BIOFEEDBACK TRAINING AND COGNITIVE STYLE: AN ELECTROPHYSIOLOGICAL LEARNING STUDY

by

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GENERAL INTRODUCTION

Perhaps the most fascinating aspect of man's attempts to understand his own motives and behavior is the fact that he is so similar to, yet so different from, every other man. As in nature where snowflakes and sand-grains are unique, the very cells that comprise man's physical being are highly specific and variable in function. Yet, as snowflakes group to form homogeneous white blankets and sandgrains combine to create perceptually uniform deserts, so do the cells of man blend themselves toward a common form, remarkably similar in structure, function, and limitation.

So it goes, this state of affairs: through all of nature, up the phylogenetic scale, culminating in the complex differences yet obvious similarities in man's overt behavior. Although more difficult to specify, who would disagree that man's covert behavior is permeated by the same inherent phenomenon? As cognition is externalized through verbal behavior, and subsequently measured or evaluated, it becomes apparent that thinking possesses the same paradoxical quality inherent in all other forms of matter; man's most highly sophisticated and complex behavior: his cognitive interactions with himself and his environment, the most significant implement he has for understanding his behavior and experience, is itself servant to the same phenomenon at which man has marvelled for thousands of years.

Perhaps because of its significant role as an implement in his search, or perhaps only because it remains so elusive of his current scientific "sophistication," the practical implications of the differences and similarities in man's thinking have been relatively unexplored. Philosophers

and others have been contemplating for centuries, viz., there has been a lot of thinking about thinking, but in terms of practical, empirical knowledge we are relatively ignorant of the specific effects of man's variable cognitive behavior.

As we have attempted to understand even our simplest behaviors, Western man has, through his own thinking, determined that empirical data resulting from scientific investigation is deemed a highly valued source of evidence in support of hypotheses concerning his thoughts and intuitions about himself and his environment. Consequently, increased evidence for the existence of differential generalized cognitive behavior, as well as increased knowledge concerning learning and performance variables among those of us who differ markedly in "cognitive style"[1] can presumably be acquired through careful experimentation.

It is the general purpose of this paper to engage in such controlled investigation in the hope of potentially increasing our knowledge about the relationship between thinking and behavior: it will attempt to demonstrate both behavioral and electrophysiological evidence that (1) individuals use different generalized cognitive strategies in dealing with their environments, and (2) those individuals who differ maximally in such strategies, that is, those individuals most polarized in "cognitive style," show differential rates of learning on strategy-specific tasks (i.e., tasks requiring more of one cognitive mode than another).

More specifically, a unique task situation (e.g., biofeedback training) will be used to discern whether persons engaging in two essentially polarized stragegies of generalized cognition (intuitive vs. analytic thinking) and two counterposed perceptual response tendencies (spatial vs. verbal responding) differ reliably in terms of amount and rate of learning within the task. The explicit appropriateness of biofeedback training as a task

with respect to this particular research question will be emphasized. Relevant literature reviews of biofeedback training and cognition, along with detailed discussion of rationale and hypotheses, methods, results, and conclusions, both empirical and theoretical, are presented.

CHAPTER 1

INTROOUCTION, RATIONALE, AND HYPOTHESES

Biofeedback training is a technique through which an individual can acquire voluntary control over a specific physiological process through his use of continuous information or feedback from that on-going physiological process. More specifically, biofeedback refers to an individual receiving immediate, ongoing information about one or more of his bodily processes, such as heart rate, skin temperature, brain waves, blood pressure, or muscle tension. The bioelectric information is usually provided in the form of a needle on a meter, by a light or sound, or by allowing the person to observe the physiological record as it emerges from the monitoring instrument. Biofeedback training is thus the individual's use of the bioelectric information (i.e., feedback) to voluntarily change or control the specific process or response being "fed back." (For a detailed description of the theoretical issues and empirical evidence underlying current work in the area of biofeedback training, see Appendix A.)

Current work in the area of biofeedback training has increasingly addressed itself to the role of independent cognitive variables that may be operating within the biofeedback setting. More specifically, the role of "cognitive styles," or generalized thinking patterns or strategies, have become extremely popular in the literature attempting to determine predictors of performance in biofeedback training. Numerous personality variables have also been researched in this regard. (For a

detailed description of the behavioral and electrophysiological evidence supporting current work in the area of cognitive style, see Appendix B.)

The present study will primarily attempt to demonstrate that individual differences in cognitive style can predict differential learning curves within a biofeedback training task. More specifically, variability in the amount and rate of low arousal electroencephalographic (EEG) and electroymyographic (EMG) biofeedback training will be examined as a function not only of cognitive style and a specific personality measure (e.g., ego strength), but also (for EEG trainees) as a function of cerebral hemisphere electrode training site. Thus, it will be determined whether performance in low arousal biofeedback training is more accurately predictable from hemisphere electrode placement and cognitive preference test scores than from test scores alone.

In considering cognitive style or personality measures that might independently predict individual differences in low arousal biofeedback training, the intuitive-analytic distinction, the spatial-verbal dichotomy, and the ego strength dimension seemed appropriate.

Independent Variables

Intuitive-analytic thinking. The intuitive-analytic continuum of thinking emphasizes the distinction between logical, rational thought based on rather explicit, rule-following processes in combining relatively objective and often quantified material on the one hand, and more rapid, implicit and global forms of thought on the other (Baumgardner, 1973). That is, the intuitive mode is impulsive, hunch-based, experiential and reflexive, while the analytic mode is rational, logically-based, learned

and reflective (Cohen, 1974). For example, in the case of career choice in college, students can use "gut feelings" and emotional satisfaction as a basis for choice of majors or they can rely on more analytic factors, such as grades and vocational-aptitude test scores (see Baumgardner, 1976). Decision processes according to this perspective are described by the relative dominance of an intuitive vs. analytic orientation (i.e., the preferential use of one generalized mode over the other while necessarily vacillating between them). Finally, the dichotomous endpoints of this continuum of thinking have also been viewed as a developmental progression from a more primitive mode of thinking (e.g., intuitive) to a more differentiated mode (e.g., analytic) (Gilbert and Rappoport, 1975; Quinn, 1975).

In view of the descriptive similarity between the intuitive-analytic continuum and the cognitive requisites for bidirectional biofeedback training (see Appendeix A, Section 4), persons demonstrating a preference for the intuitive mode might perform better within low arousal training than those preferring the analytic mode. Conversely, persons demonstrating a preference for the analytic mode might perform better within high arousal training than those preferring the intuitive mode. More specifically, the passive, global set apparently required for success within low arousal training (e.g., passive volition) might be more easily maintained by the intuitive individual, while the active, effortful set required for success within high arousal training (e.g., active volition) might be more easily maintained by the analytic individual.

Spatial-verbal preference. The spatial-verbal dichotomy also appears useful as a predictor of differential performance in biofeedback training.

Spatial processing has been reported to activate primarily the non-dominant or right hemisphere, while verbal processing apparently activates the dominant or left hemisphere (Galin and Ornstein, 1972; Ornstein & Galin, 1973, 1975). Since the right hemisphere has been reported to mediate activities similar to low arousal biofeedback training, such as hypnosis (Morgan, MacDonald & Hilgard, 1974; Bakan, 1971) and meditation (Frumkin & Pagano, 1976; Harrison, Warrenburg & Pagano, 1976), persons demonstrating a preference for spatial processing via perceptual response measures (i.e., relative right vs. left hemisphere activation) may perform better within low arousal biofeedback training than persons preferring verbal processing (i.e., left vs. right hemisphere activation). Conversely, persons demonstrating a preference for verbal processing via perceptual response measures may perform better within high arousal training than those preferring spatial processing.

Spatial-intuitive/verbal-analytic modes. The integration of the intuitive-analytic continuum and the spatial-verbal dichotomy, that is, preferred generalized cognitive strategies on the one hand, and task relevant perceptual response tendencies, on the other, might result in greater predictability of performance during training than either duality alone. However, this will be the case only to the extent that aligned constructs from the dualities are, in fact, complementary within a particular directional training task. In low arousal training, for example, a greater correlation should be found between training performance and integrated constructs (e.g., spatial-intuitive mode) than between training and either construct alone (e.g., intuitive, spatial modes separately). Similarly, a greater correlation should be found between high arousal training performance and the integrated, verbal-analytic mode than between training and either of these constructs alone.

Ego strength scale. Finally, available evidence suggests that the ego strength scale (Barron, 1956) might also predict performance in biofeedback training. Reportedly a measure of coping ability, the scale characterizes high ego strength individuals as having a greater ability to accurately assess and respond to environmental stimuli through the use of fewer "ego defense mechanisms" than low ego strength individuals (Roessler, 1973; see Appendix B, Section 2). More important, the scale has been used as a reliable predictor of physiological discrimination and responsiveness to various stimuli (see Roessler, 1973). Extending this idea, Hardt (1975) has suggested that the more responsive high ego strength individuals change more appropriately to physiological feedback, and thus, should perform better in biofeedback training (both low and high arousal training) than low ego strength individuals.

In summary, the dichotomy of cognitive requisites for bidirectional biofeedback training is simlar, at least descriptively, to the distinctions often cited between intuitive vs. analytic thinking and spatial vs. verbal responding, as well as to the variability in receptivity and physiological responsiveness of high vs. low ego strength individuals. That is, the non-attached, non-linear, implicit, global, and spatially diffused description of passive volition (see Appendix A, Section 4), the unique strategy apparently required for low arousal biofeedback training, appears similar to the non-linear, experiential, implicit, hunch-based, and global description of the predominantly intuitive thinker with spatial response preferences. In addition, spatial responding and activities similar to low arousal biofeedback training (e.g., meditation, hypnosis) have both been linked to the non-dominant or right cerebral hemisphere (Morgan, et al., 1974; Bakan, 1971; Frumkin & Pagano, 1976).

Conversely, the focused, active, effortful, and "rule following" strategy appropriate for high arousal biofeedback training (e.g., active volition) seems quite similar descriptively to the linear, reflective, logical, "hypothesis testing" strategy of the predominantly analytic thinker with verbal response preferences.

In view of these similarities, bidirectional biofeedback training can be considered a useful technique for investigating behavioral differences among individuals preferring either unipolar construct (e.g., intuitive or spatial *vs*. analytic or verbal modes), and particularly both unipolar constructs (e.g., spatial-intuitive *vs*. verbal-analytic modes).

Hypotheses

On the basis of the relationships cited thus far between biofeedback training and spatial-intuitive *vs*. verbal-analytic cognition, and in view of the findings presented in Roessler's (1973) research review and Hardt's (1975) observational data regarding the relationship between ego strength and successful biofeedback training (see Appendix B, Section 2), general traning hypotheses for the present investigation are as follows.

1. Subjects demonstrating preference for a spatial-intuitive cognitive mode on the basis of convergent questionnaire data (see Chapter 2) will acquire voluntary control over low arousal EEG and EMG feedback stimuli (defined as statistically reliable decreases from EEG frequency and EMG amplitude baseline levels) to a reliably greater degree[2] and at a reliably greater rate than subjects demonstrating preference for a verbal-analytic cognitive mode.

2. Subjects displaying high ego strength (i.e., relatively high Es scores on Barron's Ego Strength Scale) will acquire voluntary control over low arousal EEG and EMG feedback stimuli to a reliably greater degree and at a reliably greater rate than subjects displaying low ego strength (i.e., relatively low Es scores).

3. Spatial-intuitive subjects will not differ reliably from high ego strength subjects in low arousal training (i.e., both will train reliably: equal amounts and rates).

4. Verbal-analytic subjects will not differ reliably from low ego strength subjects in low arousal training (i.e., neither will train reliably).

As Kimmel (1974) has pointed out, cognitive mediation in biofeedback training differs from the daily use of generalized cognitive strategies which are brought to the training situation. In other words, deliberate cognitive strategies such as specifically imagined situations or direct imagery (perhaps from pre-training instructions) must play a different role theoretically than measurable, generalized cognitive preferences which are not elicited specifically for the task. Therefore, without invoking the former (cognitive mediation) as a specific shortcoming within theoretical explanations of biofeedback training (unless circumstances require it), the present investigation has focused primarily on the latter, or the effect of existing generalized preferences for specific cognitive modes on the biofeedback task, where no instructional elicitation of particular "mediated" cognitive activity is present.

Consequently, in reference to Hypothesis 1, since effortful, focused cognition has been shown to be counterposed to successful low arousal biofeedback training (cf. Green and Green, 1973a, 1973b; Fehmi, 1975), it is reasoned that intuitively-oriented subjects with spatial response preferences should more rapidly discover that "turning off" their secondary, verbal-analytic processes (thus following their more "primitive" inclinations) facilitates the maintenance of the passive set required for desirable feedback. Consequently, these subjects' disposition toward a cognitive mode resembling the passive set required for desirable feedback should enhance their success at the task relative to verbal-analytic subjects.

Conversely, analytically-oriented subjects with verbal response preferences might not only take longer to discover that effortful strategies

are fruitless toward acquiring desirable feedback, but they may also find it more difficult to terminate such differentiated tendencies, even when their counterproductiveness is realized. In other words, their disposition toward a cognitive mode counterposed to the set required for desirable feedback should diminish their success at the low arousal task relative to spatial-intuitive subjects.

Finally, in reference to Hypothesis 2, the superior physiological discrimination and responsiveness of high ego strength individuals, as indicated by Roessler (1973) and Hardt (1975), provides sufficient basis for postulating that successful biofeedback trainees should display higher Es scores than unsuccessful trainees.[3]

When considering that the characteristics of both spatial-intuitive and high ego strength individuals appear conducive to low arousal biofeedback training, there seems little reason to postulate differences in the amount and rate of their training, as Hypothesis 3 denotes. Similarly, as indicated in Hypothesis 4, since both verbal-analytic and low ego strength subjects apparently possess cognitive profiles contraindicated for low arousal control, neither should be expected to learn it reliably.

Cerebral hemisphere electrode placement. As delineated in Appendix B, Section 3, examination of more specific variables that might be salient in terms of individual differences in biofeedback training reveals that the amount and rate of EEG frequency training may be predictable from cerebral electrode placement. On the basis of research by Galin and Ornstein (1972, 1974) and Ornstein and Galin (1973, 1975) demonstrating hemispheric specialization of cognitive function, and Dumas and Morgan (1974), Ornstein and Galin (1973), Doyle *et al*. (1974), and Patterson (1975) revealing additional specificity of EEG lateral asymmetry by cognitive style (see Appendix B, Section 3), the following hypotheses were also tested.

5. (a) Subjects demonstrating preference for a spatial-intuitive cognitive mode and who have active electrodes placed over their right cerebral hemisphere (O_8-T_4) will acquire voluntary control over low arousal EEG feedback stimuli to a reliably greater degree and at a reliably greater rate than subjects demonstrating preference for a spatial-intuitive cognitive mode having electrodes placed over their left cerebral hemisphere (O_7-T_3).

   (b) Spatial-intuitive subjects with right hemisphere-placed electrodes will acquire voluntary control over low arousal EEG feedback stimuli to a reliably greater degree and at a reliably greater rate than verbal-analytic subjects with left hemisphere-placed electrodes.

   (c) Spatial-intuitive subjects with right hemisphere-placed electrodes will acquire voluntary control over low arousal EEG feedback stimuli to a reliably greater degree and at a reliably greater rate than verbal-analytic subjects with right hemisphere-placed electrodes.

6. (a) Spatial-intuitive subjects with left hemisphere-placed electrodes will acquire voluntary control over low arousal EEG feedback stimuli to a reliably greater degree and at a reliably greater rate than verbal-analytic subjects with left hemisphere-placed electrodes.

   (b) Spatial-intuitive subjects with left hemisphere-placed electrodes will acquire voluntary control over low arousal EEG feedback stimuli to a reliably greater degree and at a reliably greater rate than verbal-analytic subjects with right hemisphere-placed electrodes.

7. Verbal-analytic subjects with left hemisphere-placed electrodes will not differ reliably in the degree or rate of low arousal training from verbal-analytic subjects with right hemisphere-placed electrodes (i.e., neither will train reliably).

Considering that the two cerebral hemispheres are activated via qualitatively different input stimuli and that the specific conditions under which each is activated closely resemble the differences cited between spatial-intuitive and verbal-analytic functioning, Hypotheses 5, 6, and 7 become clear. Specifically, if the right hemisphere is activated during spatial-intuitive functioning (Galin and Ornstein, 1972, 1974; Ornstein and Galin, 1973, 1975), and additionally, demonstrates a specificity shown to be responsible for task lateral asymmetry in subjects preferring this mode

(Ornstein and Galin, 1973; Patterson, 1975), then this sensitivity of the right hemisphere could reasonably extend to trainability within a task whose requisites are associated with its functional characteristics.

In other words, if right hemisphere activity (i.e., its sensitivity) distinguishes "intuitive laterality" from "analytic laterality,"[4] then right hemisphere activity might also distinguish spatial-intuitive from verbal-analytic subjects in low arousal EEG biofeedback training, as well. Moreover, identical logic would appear to hold for the converse, that is, left hemisphere activity: its verbal-analytic properties and its responsibility for laterality in subjects preferring this cognitive mode might similarly distinguish verbal-analytic from spatial-intuitive subjects in high arousal EEG training. This rationale, along with earlier discussion of the posited superior role of a passive set for low arousal and an active set for high arousal biofeedback training (see Green and Green, 1973a, 1973b, 1974a, 1974b; Fehmi, 1975), form the basis for Hypotheses 5, 6, and 7.

In view of this rationale, it is expected that the generalized tendencies of spatial-intuitive subjects, in conjunction with EEG electrode placement over their "preferred" (i.e., sensitive) right hemisphere (O_8-T_4),[5] should maximally facilitate maintenance of the passive set required for desirable, low arousal alterations in EEG frequency. Thus, spatial-intuitive subjects with right hemisphere-placed electrodes should be superior in low arousal training to all other training groups (Hypotheses 5a, 5b, and 5c). Moreover, because the spatial-intuitive mode seems very appropriate to the experimental task, it is expected to outweigh the effect of left hemisphere-placed electrodes (i.e., over the "non-preferred " hemisphere), allowing for greater and faster learning in this group than left or right hemisphere-placed electrodes in verbal-analytic subjects (Hypotheses 6a and 6b).

Finally, since verbal-analytic sybjects are not expected to train reliably toward low arousal (see Hypothesis 4), it is reasoned that electrode placement should make little if any difference (see Hypothesis 7).

Recapitulation

To further investigate the relationship between cognition and overt behavior, subjects demonstrating preference for either a spatial-intuitive or verbal-analytic cognitive mode will undergo rigorous, low arousal biofeedback training. Biofeedback training has been shown to be particularly appropriate for such an investigation since the specific cognitive requisites for the task are reported to be consonant with the characteristics of spatial-intuitive and verbal-analytic cognitive functioning, as well as the lateral specialization of function within the two cerebral hemispheres. More specifically, independent (matched) groups of spatial-intuitive and verbal-analytic subjects will receive low arousal EMG biofeedback training (e.g., frontalis amplitude lowering), or low arousal, hemisphere-specific EEG biofeedback training (e.g., dominant frequency lowering). Ego strength (Es) scores from the initial sample and all subsamples will be correlated with scores from the cognitive preference measuring instruments used for subject selection, as well as used to predict successful vs. unsuccessful biofeedback training. Any reliable pre-post changes on the intuitive-analytic and ego strength measures will be examined in order to evaluate their specific relationship to the biofeedback training process. Finally, an attempt will be made to provide additional evidence that EEG and EMG parameters can be brought under "voluntary control" (i.e., conditioned above or below resting baselines using operant methods).

Empirical support within the present investigation for differential amounts and rates of learning (within a biofeedback setting) among subjects

varying in cognitive orientation would offer (1) a plausible alternative hypothesis for studies reporting negative training results (i.e., further insight into the situational dynamics of, and cognitive requisites for, biofeedback training), (2) additional evidence for behavioral variability among persons demonstrating preferences for either spatial-intuitive or verbal-analytic cognitive styles, (3) insight into an additional personality variable (e.g., ego strength) that might play a significant role in biofeedback training and related tasks, and (4) additional insight into the lateral specialization of cognitive modes.

CHAPTER 2

DESIGN AND METHODS

Subjects

Undergraduate and graduate students from a wide variety of introductory and upper level classes at Kansas State University were used. All educational levels and a large number of major areas of study were represented. In addition, residents of the Manhattan community representing a wide variety of age and occupations were used. Subjects were told the general purpose of the experiment, but specific hypotheses were not discussed. Since monetary remuneration was unavailable for the present investigation, progress throughout the experiment was contingent upon the subjects' intrinsic motivation.[6]

Cognitive Preference Instruments and Ego Strength Scale

Intuitive-analytic questionnaire. Subjects preferring either intuitive or analytic cognitive modes (hereafter referred to as intuitive or analytic subjects) were obtained via the administration of a questionnaire constructed by Baumgardner (1973) to 693 volunteers. At this time, the subjects were informed that the questionnaire simply inquired into their thinking patterns about college majors. In addition, they were informed that a subgroup of them would be asked to meet with the author in the near future to complete two additional questionnaires, and that subsequently, an even smaller number of that group would be asked to voluntarily engage in 5 weeks of intensive biofeedback training. Finally, lefthanded persons, as well as those individuals who had had experience with meditation, biofeedback training, yoga,

or any other relaxation technique, were asked to refrain from completing the questionnaire (Baumgardner's questionnaire and details concerning its construction are presented in Appendix C, Section 1).

Analysis of responses resulted in a relatively normal distribution of ordered index scores (cf. Baumgardner, 1976). Three hundred right-handed subjects (with no familial history of lefthandedness) were obtained by selecting 150 scores from each tail of the index score distribution (i.e., 150 intuitive and 150 analytic subjects).

Word-shape Preference test. Computer selected intuitive and analytic subjects were contacted by postcard and informed of their selection for the next phase of the experiment. They were informed of a scheduled meeting with the author, during which time they would be asked to complete one additional questionnaire and a simple pencil-and-paper test. In addition, they were informed that telephone contact by the author would subsequently be made to those selected for the final phase of the experiment (viz., biofeedback training).

Of the 300 subjects contacted by postcard, 195 participated in the next phase of the experiment. Upon arrival, they were administered the Word-Shape Preference Test (Galin and Ornstein, 1974) designed specifically for distinguishing subjects with verbal perceptual response tendencies (i.e., relatively more left hemisphere activity) from those with spatial response tendencies (i.e., relatively more right hemisphere activity). The test resulted in a verbal score (V: number of items sorted verbally) and a spatial score (S: number of items sorted spatially) for each subject. Errors were anticipated to be minimal and were assumed to be randomly distrubuted. (Galin and Ornstein's Word-Shape Preference Test and details concerning its construction and administration are presented in Appendix C, Section 2.)

Ego strength scale. The second portion of each session was devoted to the administration of the Ego Strength (Es) Scale (Barron, 1956) of the Minnesota Multiphasic Personality Inventory (MMPI), since this measure has been reported to predict physiological responsiveness (Roessler, 1973) and successfulness in biofeedback training (Hardt, 1975). (Barron's Ego Strength Scale is presented in Appendix C, Section 3).

Trainee Selection, Group Assignment, and Final Instructions

For the purpose of obtaining training groups which converged upon extreme but relatively homogeneous cognitive styles, it was assumed that verbal perceptual response tendencies were positively related to analytic cognitive activity and that spatial perceptual response tendencies were positively related to intuitive cognitive activity. On the basis of this assumption, 16 subjects with the most extreme intuitive index values (i.e., highest z scores) and the highest spatial scores (i.e., spatial extreme), as well as 16 subjects with the most extreme analytic index values (i.e., lowest z scores) and the highest verbal scores (i.e., verbal extreme) were retained from the group of 195 subjects described above to participate as trainees in the balance of the experiment. The scores of these subjects on Barron's Es scale (hereafter referred to as ego strength (Es) scores) were not considered toward final trainee selection. However, trainees with relatively high and low ego strength were assumed to be discernible as those scores distributed themselves among selected subjects.

Following random assignment of spatial-intuitive (SI) trainees to left hemisphere EEG (LHSI group; n = 4), right hemisphere EEG (RHSI group; n = 4), or frontalis EMG (SI-EMG group; n = 8) training, and verbal analytic (VA) trainees to left hemisphere EEG (LHVA group; n = 4), right hemisphere EEG (RHVA group; n = 4), or frontalis EMG (VA-EMG group; n = 8) training, contact was made by mail. All trainees were asked to assemble

with the author prior to laboratory training sessions. In addition, each trainee received a brief introductory paper describing EEG and EMG biofeedback training. (This introductory paper is presented in Appendix C, Section 4).

The primary purpose of the group meeting (held one week before baseline recording) was to familiarize trainees with the laboratory, construct the daily baseline/training schedule, and to answer questions. More specifically, proper electrode application and removal (both EEG and EMG) was demonstrated and explained, more detailed explanations of EEG and EMG bioelectric activity (including training goals) were presented, and common causes of physiological recording artifacts (especially EEG) were reviewed and emphasized. In addition, the bogus scoring method employed during administration of the Word-Shape Preference Test was explained at the meeting. Finally, the trainees were asked to list their personal physician's name and all prescription drugs currently being used (along with any health problems) and were instructed to consult with their physicians if at any time during training dosage modifications appeared necessary.

Apparatus and Instrumentation

Training and recording rooms. Laboratory rooms appropriate for psychophysiological experiments at Kansas State University were used. The recording room (3½ x 12 feet) was centrally located between two rooms (each 12 x 12 feet) partitioned off to create a total of four training rooms (each 12 x 6 feet).

The training rooms were deliberately furnished to maximize comfort for the trainees. Specifically, the floors were wall-to-wall carpeted and the walls contained pictures and informal drawings. Windows were

covered with heavy blankets (to eliminate light entry) and long, thick draperies (matching those over the one-way recording room windows). Each training room contained a low-back, medium-sized, overstuffed chair, an adjacent table containing a feedback instrument, stereo headphones, intercom relay module, lapel microphone, and electrode materials. Distributed throughout the training rooms were miscellaneous items such as small tables and lamps, wastebaskets, bookshelves, knickknacks, file cabinets, etc. Extension lines ran from each feedback instrument, headset, and intercom module to the recording room and were obscured by carpeting and furniture as much as possible. Thus, typical "research materials" remained deliberately absent or hidden. The predominant color of the training rooms was beige, and each had the atmosphere of a comfortable, informal sitting room.

The recording room contained major data acquisition equipment, a four-channel intercom console, one small lamp, two Realistic Solo-10 high efficiency loudspeakers, and additional miscellaneous recording materials.

<u>EEG training-recording equipment and feedback stimulus</u>. Bioelectric scalp potentials were recorded with three silver/silver chloride electrodes housed in plastic (Biofeedback Technology, Inc.) secured by a rubber headband to either the left or right cerebral hemisphere over the temporal and occipital lobes (O_7-T_3 or O_8-T_4: 10-20 International System; Jasper, 1958). Upon lightly scrubbing placement sites with alcohol, an electrode centered just above the ipsilateral eyebrow served as a reference, while the active temporal and occipital electrodes detected EEG activity differentially (i.e., bipolarly). Biogel (Biocom, Inc.) was used as the interfacing (conducting) medium. Electrode resistances were maintained below 5,000 ohms.

The raw EEG from either the left hemisphere (LHSI and LHVA groups) or right hemisphere (RHSI and RHVA groups) was amplified, rectified, and averaged by an Autogen 120a Encephalograph Analyzer (frequency resolution better than .25 Hz (Autogenic Systems, Inc.), where separate meters displayed average amplitude and alpha index (per cent alpha) over each entire 40-minute training session.[7] Except during baseline recording, potentials falling within a dominant frequency range of 2-20 cycles per second (Hz) controlled the auditory feedback presentation (30 dB musical tone ranging from approximately 50-1000 Hz) via Hybrid Spectrum Analysis. Reaching the trainee through Numark Model DH-15B stereo headphones (8 ohm), the frequency of the feedback signal was prportional to the dominant frequency of his EEG within the designated upper and lower limits of the instrument's bandpass settings (i.e., 2-20 Hz).

More specifically, the feedback stimulus was "on" almost constantly, since rarely did a trainee's EEG fail to meet such dominant frequency criteria. These frequency settings were deliberate in order that the trainee's task was one of attempting to keep the rising and falling feedback stimulus at a low level of pitch to effect lower dominant frequencies (continuous-analogue feedback), in contrast to the often distracting task in which the feedback stimulus is activated only upon the trainee's meeting more specific frequency and amplitude criteria, such as alpha (8-13 Hz above 24 μV) or theta (4-7 Hz above 10 μV) ("on-off:" binary feedback). Moreover, continuous-analogue feedback has been shown to be more efficient than binary feedback in eyes-closed EEG training (Travis, Kondo & Knott, 1974). Finally, it should be noted that the feedback stimulus was entirely frequency controlled (i.e., it was relatively unaffected by amplitude fluctuations).

Each EEG trainee's amplified, instanteous frequency activity traveled as a variable D.C. voltage from the feedback instrument to the recording room, where two minute epochs of integrated dominant frequency were computed on-line every 2 minutes, 5 seconds by an Autogen 5100 Digital (Time Period) Integrator/Wave Form Analyzer (4 digit: accuracy = .3%) (Autogenic Systems, Inc.). A Galitzer Four Channel Intercom console was used to provide each trainee with verbal feedback of integrated (2 minute) dominant frequency 10 times per session. A lapel microphone was used by the trainee to communicate with the experimenter when necessary.

EMG training-recording equipment and feedback stimulus. Muscle action potentials from the frontalis were recorded with three silver/silver chloride electrodes housed in plastic (Biofeedback Technology, Inc.) secured by a rubber headband. Following a light alcohol scrub of the appropriate areas, two active electrodes were placed one inch above the center of each eyebrow, with the reference electrode centered directly between them (i.e., approximately 2 inches from each active electrode and approximately 1½ inches above the nasion). As with EEG recording, Biogel was used as the interfacing (conducting) medium and electrode resistances were maintained below 5,000 ohms.

The raw EMG from the frontalis muscle was amplified and rectified by an Autogen 1500a Feedback Myograph with a standard bandpass of 100-200 Hz (high pass: 30dB/octave; low pass: 12dB/octave) (Autogenic Systems, Inc.). Except during baseline recording, frontal EMG potentials controlled the auditory feedback presentation, which consisted of continuous "clicks" (approximately 30db) whose frequency varied in logarithmic proportion to instantaneous changes in the EMG. Thus, each trainee received continuous-analogue "click" feedback which reached him via Numark (DH-15B) stereo headphones.

Each trainee's amplified and rectified instanteous frontal EMG traveled as a variable D.C. voltage from the feedback instrument to the recording room, where two minute epochs of integrated amplitude (μV, root mean square) were computed on-line every 2 minutes, 5 seconds by a separate Autogen 5100 Digital Integrator. The Galitzer Four Channel Intercom system and separate lapel microphone were used for communication between trainee and experimenter, as well as to provide the trainee with verbal feedback of integrated (2 minute) EMG amplitude 10 times per session.

Procedure

Following trainee selection and group assignment, each of the 32 trainees was scheduled for preliminary instruction in laboratory procedures and daily sessions of baseline recording/biofeedback training. Each session lasted approximately 55 minutes (40 minutes of actual baseline recording or training). Trainees were schedules at the same time of the day (9:30 am to 9:30 pm), four consecutive days per week (Monday through Thursday), for five weeks in all (one week of baseline recording and four weeks of training). Thus, each trainee received three consecutive days (120 minutes) of basline recording[8] and 16 days (640 minutes) of biofeedback training.

Upon arrival to the lab for the first session, each trainee was introduced to the data acquisition system, as well as his respective feedback instrument and accessories. Trainees were randomly assigned to one of two EEG or EMG training instruments (and rooms), the combination of which was held constant throughout the experiment. Electrode attachment procedures were carefully reviewed and repeatedly practiced until satisfactory application and placement became routine.[9] Appropriate posture and potential sources of artifact (e.g., excessive body movements, neck

turning, eye movements/blinks, teeth clenching, etc.) related to EEG or EMG recording were reviewed. At this time, trainees were prompted as to the possible contaminating effects of chronic drug use on accurate physiological baseline recording and subsequent biofeedback training, and were thus reminded to refrain from such non-prescription drug use throughout the experiment.

During the second session (first baseline session), trainees were satisfactorily "hooked up" (two at a time from 9:30 am to 2:30 pm; four at a time from 5:30 pm to 9:30 pm), after which time the experimenter monitored resting EEG or EMG activity while the subjects sat in total darkness with their eyes closed in the following manner: Immediately following verification of adequate electrode attachment/placement, posture, and loosening of clothing (e.g., shoes, belts, etc.), the experimenter extinguished all training room lights and retired to the recording room, at which time he instructed the trainees over the intercom as follows:

> We are now ready to begin/continue baseline recording, which is simply a method whereby we can determine the nature of your brain waves or muscle tension while you sit comfortably. Please don't be nervous, as this is not a test or anything like that. Simply remain as relaxed as you can, thinking of nothing in particular- while keeping your eyes closed and your body very still- just as you might do if you reserved 40 minutes during the day for this type of relaxation. Remember to keep your head bent forward just a little and your face and jaw very relaxed, OK? Does anyone have a question? Now we'll begin.[10]

Following a two-minute acclimation period, the experimenter acquired ten values (spaced 4 minutes, 10 seconds apart) of integrated (2 minute) dominant frequency or integrated EMG amplitude from each trainee over the next 40-42 minutes. In addition, average amplitude and alpha index values were obtained for EEG trainees immediately following each session, these values reflecting activity over the previous 2000 seconds (33.3

minutes). Identical data were obtained during and following the subsequent sixteen training sessions.

At no time during this or subsequent baseline sessions was the trainee permitted to experiment with a feedback stimulus. However, following the last baseline session, each trainee was permitted to listen to and briefly experiment with the feedback stimulus available to him for explanatory purposes. More specifically, this experimentation was in conjunction with a detailed description of the training procedure, task requirements, and training goals. This was the final itemized description of the training procedure given and it included desired/undesired alterations in feedback stimuli, administration of verbal feedback, specific training goals (e.g., lowering EEG frequency or EMG amplitude from baseline), and minimization of artifacts. The trainees were not offered any specific strategy for successful training, but were informed once again that self-regulation of these processes was possible.

Upon each group of trainees' arrival for the first training session, electrode attachment/placement was verified, after which time each trainee was permitted to further experiment briefly with his respective feedback stimulus and to adjust volume for maximum comfort. In most cases, this adjustment resulted in a stimulus intensity of approximately 30 dB. The experimenter then monitored electrophysiological activity (as described) while the trainees underwent eyes-closed biofeedback training in total darkness. (It was assumed that the trainee's head position during training would act as an effective control for sleep onset.)

After extinguishing the lights and returning to the recording room, the experimenter instructed the trainees as follows:

> We are now ready to begin/continue biofeedback training. Those of you training with EEG instruments know that your task is to keep the musical tone feedback as low in pitch as possible for as long as possible in order that your average frequency levels will be reduced. Those of you training with EMG instruments know that your task is to keep the 'click' rate as slow as possible for as long as possible in order that your average amplitude levels will be reduced. Ten times during the session (about every 4 minutes) I will interrupt both/all of you and tell you either what your average EEG frequency or your average EMG amplitude was over the previous two minutes, so that you will know how well you are doing as you go along, OK? Remember, even if you decrease your EEG or EMG values only a small amount during each 2-minute interval, that's still good. (Naturally, however, you want to try to decrease them as much as you can.) Once again, try to be as still as possible throughout the session (especially minimizing face/jaw/eye movements and teeth clenching), while always keeping your eyes closed and your head bent forward just slightly. Also, if you have to alter your position a little, adjust your feedback volume, or speak to me for some reason, please do so only during or immediately following verbal feedback. Finally, remember not to try too hard at this task. Like any other task, trying too hard can be as detrimental as not trying hard enough. Does anyone have a question? OK, now we'll begin.

These instructions were read to all trainees before each training session. Miscellaneous announcements occasionally preceded these remarks, but for all sessions the above instructions were delivered in full. It should be noted that activation of the intercom system de-activated the trainee's ongoing feedback stimulus, so that instructions and verbal feedback were more easily digested.

Finally, EEG trainees were rescheduled for additional lab sessions when inadequate electrode attachment or electrical interference prevented reliable, noise-free EEG recording. Approximately one-fourth of the EEG subjects required rescheduling for this reason.

Additional Feedback, Posttests, and De-Briefing

In the interest of maximizing feedback regarding his progress in the experiment, each trainee received a summary of his electrophysiological

activity and related alterations each week (every 4 sessions).[11] Beginning the first week with baseline values (averaged over 3 sessions), the trainees were provided with their daily average EEG or average EMG integrated values for the week, and in addition, these values' respective per cent change from both baseline and the preceding week's activity. Moreover, the rank ordered distribution of weekly per cent change values from baseline for all trainees was updated regularly and posted in the laboratory waiting room throughout the experiment. Trainees' names were not included on these posted distributions. Finally, soon after the sixteenth session, each trainee received a letter of thanks from the author along with a complete summary of his EEG or EMG activity for each of the sixteen days and four weeks, as well as these values' updated per cent change from baseline, the preceding week's activity, and from his "best day" (i.e., lowest daily average).

During the final week of laboratory sessions, all trainees were re-administered the Intuitive-Analytic Questionnaire and Ego Strength Scale outside the laboratory for the purpose of detecting alterations in intuitive-analytic index and Es scores over the course of the experiment. (Trainees took the questionnaires home on Tuesday of the final week (Session 14) and returned them Wednesday or Thursday (Sessions 15 or 16)).

In addition, on the final day of the experiment, all trainees received a questionnaire constructed by the author which inquired into subjective experiences and behavioral changes that may have accompanied or followed the period during which they underwent biofeedback training. In particular, trainees were asked in the questionnaire to reflect and elaborate on the specific strategies used while attempting to effect changes in the feedback stimulus. Trainees were asked to return the questionnaires to the laboratory

at their convenience or to bring them to an informal de-briefing session held at the author's residence approximately one week after the final training session. (This post-training questionnaire is presented in Appendeix C, Section 5).

The informal de-briefing session provided a good opportunity for the author to thank all trainees for the diligent and generous contribution of their time while participating in the experiment. Moreover, it also allowed the author an opportunity to inform the trainees of the theoretical background and specific experimental hypotheses underlying the project which had been ommitted in all previous discussions.

Data Analysis

Integrated (2 minute) EEG frequency values for LHSI, LHVA, RHSI, and RHVA groups, as well as integrated (2 minute) EMG amplitude values for SI-EMG and VA-EMG groups, were independently obtained every 4 minutes, 10 seconds directly from the digital integrators. Thus, ten 2-minute epochs of average dominant frequency or average EMG amplitude were obtained for each subject within each 40-42 minute baseline and training session. EEG epochs were deleted where EMG artifact or their contaminating influences were present (i.e., where integrated frequency in adjacent epochs differed by more than 50% in either direction). Epochs were averaged resulting in a single mean (integrated) EEG frequency (IF) or EMG amplitude (I_mA) score for each subject per session. In addition, average (33.3 minute) EEG amplitude (I_eA) and alpha index (AI) session scores were obtained for each subject in all EEG groups.

The average of the first three mean IF or mean I_mA session scores was taken as the physiological baseline (i.e., "Session 0") score for each

subject. These "Session 0" means were evaluated against the means of the sixteen training sessions within a 2 x 2 x 16 per cent change analysis of variance with repeated measures on one factor (SI-VA x EEG-EMG x Sessions), in order to reveal any main effects or interactions from treatment where either cognitive style or feedback mode was disregarded. Independent 2 (SI-VA) x 16 (Sessions) analyses of variance (repeated measures, one factor) on raw mean IF and I_mA scores were also conducted in order to reveal differential EEG and EMG training by cognitive style.

The above procedure was consistently employed throughout all data analyses. That is, where raw EEG and EMG data were analyzed within separate designs, "Session 0" (baseline) values were included in each. However, where both feedback modes were analyzed within the same design, the dependent variable was per cent change from "Session 0."

To evaluate the EEG data more precisely, independent 2 (LH-RH) x 2 (SI-VA) x 16 (Sessions) analyses of variance (repeated measures) on mean IF, I_eA, and AI scores were performed in order to reveal differential group training by both hemisphere and cognitive style, and the relationships among integrated dominant frequency, average amplitude, and per cent alpha across sections.

In order to determine whether the personality construct of ego strength predicted performance during training, Es scores for experimental groups displaying reliable reductions in either IF or I_mA scores over sessions were statistically compared with the Es scores of groups showing no such reduction. Also performed were correlations between Es scores and IF and I_mA difference scores (i.e., difference between baseline and lowest of final four mean IF or I_mA scores).

Additional correlations were performed among the ego strength and cognitive preference measures, and among the cognitive preference measures and dependent baseline and training variables in order to evaluate both their relationship to each other and to electrophysiological baseline levels and training performance. Finally, *t*-tests were used to evaluate pre-post changes on the IN-AN and Es measures.

CHAPTER 3

RESULTS

Cognitive Preference Instruments and Ego Strength Scale (Pre-Training)

Descriptive data. Summarizing the variability in the scores of the questionnaire measures, Table 1 presents the ranges, means, and standard deviations (S.D.s) for the initial volunteer-subject pool (First Sample,

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Table 1 about here

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n = 693) and the 150 intuitive and 150 analytic subjects selected from the tails of the Intuitive-Analytic (IN-AN) distribution (Initial Selection) (see Chapter 2). Also presented are the ranges, means, and S.D.s of the 96 intuitive and 99 analytic subjects from these selected groups who completed both the Word-Shape Preference Test (S-V) and Ego Strength (Es) Scale (Second Sample), as well as the 16 spatial-intuitive and 16 verbal-analytic subjects selected from the Second Sample for biofeedback training (Third Sample).

As can be seen, the IN-AN distribution for all samples was slightly skewed toward the intuitive mode. Despite this, only one VA trainee (Third Sample) had an IN-AN score that was greater than 0. IN-AN ranges, means, and S.D.s differed only slightly from the First to the Third Samples. The measure successfully produced relatively extreme intuitive and analytic groups whose mean scores differed reliably (Initial Selection). This quantitative distinction increased with the subsequent matching of low IN-AN scores and high V scores, as evidenced by the reliably lower IN-AN

mean for VA trainees in the Third vs. Second Sample ($t(.001, 113)=8.02$).[12]

The S-V measure failed to produce an approximately normal distribution of spatial responders and verbal responders. As can be seen in Table 1, group S/V ratios were highly negative, despite the apparently similar ranges and S.D.s of the S and V distributions separately (Second Sample). Nevertheless, matching high S scores with high IN-AN scores and high V scores with low IN-AN scores (Third Sample) resulted in SI trainees having reliably higher S scores than VA trainees ($t(.001,30)=6.36$) and VA trainees having reliably higher V scores than SI trainees ($t(.001,30)=6.26$). Finally, error rates on the S-V measure were negligible, as anticipated (i.e., range = 0-7, $\bar{x}$ = 1.42, S.D. = 1.65 for Second Sample, n = 195). Thus, the S-V measure was adequate for the present study.

The Es measure appeared relatively stable across the IN-AN and S-V measures (Second Sample). In addition, no reliable differences were found between SI and VA groups (Third Sample) on this measure. However, a median split of the Es distribution revealed a high group ($\bar{x}$ = 49.00, S.D. = 3.54) and a low group ($\bar{x}$ = 39.81, S.D. = 3.63) that differed reliably from each other ($t(.001,30)=7.24$). Finally, a chi square analysis revealed that males displayed reliably higher Es scores than females ($x^2(.05,1)=4.25$).

Correlational data. In order to determine whether the questionnaires were measuring similar or different cognitive-perceptual variables, Pearson correlation coefficients were computed among their scores. For the Second Sample (n = 195), Pearson correlations performed on IN-AN and S scores, IN-AN and V scores, IN-AN and Es scores, S and Es scores, and V and Es scores were not reliable (e.g., all coefficients $< .10$). The Pearson coefficient computed between S and V scores was reliably negative ($r(.001)=-.98$), indicating only that errors on the S-V measure did not

meaningfully alter the forced relationship between S and V scores (see Chapter 2). Thus, although S and V scores were highly negatively related, as anticipated, the questionnaires were unrelated, in general, and were apparently measuring different cognitive-perceptual variables.

For the Third Sample (trainees, n = 32), the Pearson coefficient computed between IN-AN and S scores was reliably positive ($\underline{r}(.001)=.67$), while conversely, the coefficient between IN-AN and V scores was reliably negative ($\underline{r}(.001)=-.67$). These coefficients reflect only the degree to which high and low IN-AN scores were matched with high S and V scores, respectively.

In addition, matching IN-AN, S, and V scores as described did not alter the reliably negative correlation found between S and V scores in the Second Sample (e.g., $\underline{r}(.001)=-.98$). The Pearson coefficients computed between Es scores and IN-AN, S, and V scores were also not reliable. However, reliable correlations among these variables were found within various experimental breakdowns of the Third Sample. Specifically, IN-AN scores were negatively correlated with Es scores for SI ($\underline{r}(.05)=-.42$), SI-EMG ($\underline{r}(.005)=-.83$), and VA-EEG ($\underline{r}(.02)=-.73$) groups. The latter findings indicate that low intuitive/high analytic IN-AN scores were associated with high ego strength.

Group data. With the exception of the latter findings, no reliable differences on any of the questionnaires were found among the Third Sample training groups, except where created by the selection procedure itself. Specifically, comparisons were made among spatial-intuitive EMG (SI-EMG), spatial-intuitive EEG (SI-EEG), verbal-analytic EMG (VA-EMG), verbal-analytic EEG (VA-EEG), left hemisphere (LH), right hemisphere (RH), left hemisphere

spatial-intuitive (LHSI), right hemisphere spatial-intuitive (RHSI), left hemisphere verbal-analytic (LHVA), and right hemisphere verbal-analytic (RHVA) groups.

Baseline Recording

As a summary of electrophysiological activity in the resting state, Table 2 presents the integrated EEG frequency (IF), integrated EEG amplitude

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Table 2 about here

(I_eA), and alpha index (AI) baseline data for all EEG groups and the integrated EMG amplitude (I_mA) baseline data for both EMG groups (e.g., means and S.D.s). On the basis of these data alone, reliable mean differences were found between the LHSI and LHVA groups on the IF variable, and among LHSI, LHVA, and RHSI groups on the AI variable. Specifically, the LHSI group displayed reliably higher mean IF scores ($t(.05,6)=2.49$) than the LHVA group and reliably lower mean AI scores than the LHVA ($t(.05,6)=2.44$) and RHSI ($t(.05,6)=2.97$) groups. In addition, a test for homogeneity of independent variances (Bruning and Kintz, 1968) revealed that the SI-EEG group displayed reliably less variability than the VA-EEG group ($F(.05,7/7)=4.46$) on the I_eA variable.

As indicated in Chapter 1, no specific hypotheses concerning baseline (i.e., resting) differences by cognitive style were proposed. However, these findings indicate that RHSI subjects displayed more resting alpha than LHSI subjects and that SI-EEG subjects, in general, displayed less variability in resting amplitude than VA-EEG subjects. More important, these data indicate that LHSI subjects displayed higher resting frequency and less resting alpha than LHVA subjects.

Biofeedback Training

SI, VA, EEG, and EMG groups. In order to test the hypothesis that spatial-intuitive subjects performed better in training than verbal-analytic subjects (disregarding feedback mode) (see Chapter 1, Hypothesis 1), and in order to compare the training performance of EEG and EMG subjects (disregarding cognitive style), mean IF and I_mA scores for each training session were statistically evaluated against their respective baseline means via per cent change measures. Specifially, scores reflecting per cent change from baseline for these groups were analyzed within a 2 (Cognitive Style) x 2 (Feedback Mode) x 16 (Sessions) analysis of variance with repeated measures on one factor (e.g., Sessions).[13,14] Figure 2 compares these scores graphically.

Figure 2 about here

A reliable Sessions effect (F(.001,15/420)=12.14, MS_e=90.89) revealed that reductions in physiological activity occurred during training. Although the SI group displayed a greater average per cent change (i.e., reduction) in physiological activity over all sessions than the VA group (e.g., 25% vs. 22%), this difference was not reliable. The Cognitive Style x Sessions interaction was also not reliable. These findings indicate that SI and VA subjects did not differ in their amount or rate of reduction of physiological activity when feedback mode is disregarded. Those specific components of Hypothesis 1 were thus not supported.

Disregarding cognitive style, Figure 3 compares the mean per cent change

Figure 3 about here

scores of the EEG and EMG groups at each session. A reliable Feedback

Mode x Sessions interaction ($\underline{F}(.001,15/420)=7.85$, $MS_e=90.89$) revealed that the EMG group displayed a greater rate of reduction of physiological activity across sessions than the EEG group. Moreover, a reliable main effect for Feedback Mode ($\underline{F}(.001,1/28)=46.26$, $MS_e=3204.96$) and a reliable difference between these groups at Session 1 ($\underline{R}_{ns}$ $(.01)=8.12$)[15] revealed that the EMG group displayed greater reductions in physiological activity than the EEG group at every session. Although no specific hypothesis predicted or even addressed this potential finding, the data in Figure 3 indicate that task difficulty was a salient variable during training. Specifically, subjects found the low arousal EEG task far more difficult than the low arousal EMG task.

SI-EMG and VA-EMG groups. In order to test the hypothesis that SI subjects performed better than VA subjects in low arousal EMG training (see Hypothesis 1), mean (raw) I_mA scores for the SI-EMG and VA-EMG groups for each session were analyzed within a 2 (Cognitive Style) x 16 (Sessions) analysis of variance with repeated measures. These means are compared graphically in Figure 4. (It should be recalled that in this

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Figure 4 about here

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and subsequent analyses, baseline data were included within the ANOVA as "Session 0.")

A reliable Sessions effect ($\underline{F}(.001,16/224)=12.60$, $MS_e=0.77$) revealed that I_mA scores were reduced from baseline during training. However, no reliable main effect or interactions were found in this analysis, indicating that SI and VA subjects did not differ in their amount or rate of EMG amplitude reduction across sessions. Thus, components of Hypothesis 1 which predicted such differences were not supported.

SI-EEG and VA-EEG groups. In order to test the hypothesis that SI subjects performed better than VA subjects in low arousal EEG training (disregarding hemisphere electrode placement) (see Hypothesis 1), mean (raw) IF scores for the SI-EEG and VA-EEG groups for each session were analyzed within a 2 (Cognitive Style) x 16 (Sessions) analysis of variance with repeated measures. These means are compared graphically in Figure 5.

Figure 5 about here

A reliable Sessions effect ($\underline{F}$(.001, 16/224)=3.73, MS_e=0.438) revealed that mean IF scores were reduced during training. Moreover, a reliable Cognitive Style x Sessions interaction ($\underline{F}$(.025, 16/224)=1.86, MS_e=0.438) revealed that the two cognitive style groups displayed differential rates of IF score reduction across sessions. Further analysis of this interaction revealed that the SI-EEG group displayed reliably higher mean IF scores than the VA-EEG group at Session 0 (baseline) (R_{ns}(.001,224)=1.24), Session 1 (R_{ns}(.05,224)=0.78), and Session 2 (R_{ns}(.001,224)=1.28). These findings indicate that a reliable EEG frequency difference between SI and VA subjects was found in the resting state (e.g., SI $>$ VA), and that this difference persisted through the first two training sessions (see Figure 5). However, it should be recalled that this difference was not found where baseline data were analyzed in the absence of training data.

Further analysis of the Cognitive Style x Sessions interaction revealed that the SI-EEG group reliably reduced its mean IF scores (from baseline) at Session 4 (R_{ns}(.05,224)=0.71) and again (from Session 4) at Session 15 (R_{ns}(.05,224)=0.83). No reliable reduction (from baseline) in mean IF

scores were found at any session for the VA-EEG group, indicating that successful training for this group did not take place.

Together, these data indicate that SI subjects reduced their EEG frequency to a greater degree and at a greater rate than VA subjects. Thus, within EEG training, complete support for Hypothesis 1 is provided.

In order to determine whether EEG amplitude and alpha fluctuated across sessions along with trained frequency changes, mean I_eA and AI scores for SI-EEG and VA-EEG groups were analyzed separately within independent 2 (Cognitive Style) x 16 (Sessions) analyses of variance with repeated measures. No reliable main effects for or interactions between these factors were found within either matrix.

These findings indicate that dependent EEG variables non-contingent with the feedback stimulus (e.g., amplitude and alpha) did not fluctuate across sessions along with the feedback-contingent variable (e.g., frequency) for these groups (i.e., where hemisphere electrode placement is disregarded). Finally, although no specific hypotheses addressed this question, these findings are generally inconsistent with expectations, viz., that amplitude and alpha would fluctuate along with trained frequency changes.

EEG hemisphere groups. The following analyses were conducted in order to determine whether SI and VA subjects performed better in low arousal EEG training when the feedback stimulus reflected activity from their "preferred" *vs*. "non-preferred" hemisphere (i.e., with electrodes placed over the hemisphere whose lateralized function was aligned *vs*. unaligned with their cognitive style, e.g., right for SI subjects and left for VA subjects) (see Chapter 1, Hypotheses 5-7). Specifically, mean IF scores for the LHSI, RHSI, LHVA, and RHVA groups for each session were analyzed

within a 2 (Hemisphere) x 2 (Cognitive Style) x 16 (Sessions) analysis of variance with repeated measures. These means are compared at each session in Figure 6 and over blocks of four sessions in Figure 7.

Figures 6 and 7 about here

A reliable Hemisphere x Cognitive Style x Sessions interaction ($\underline{F}$(.05,16/192)=1.73, MS_e=0.443) revealed that reductions in mean IF scores across sessions depended upon both cognitive style and hemisphere electrode placement. Further analysis of this interaction revealed that the LHSI group displayed reliably higher mean IF scores than the RHSI (R_{ns}(.05, 192)=1.13), LHVA (R_{ns}(.001,192)=1.83), and RHVA (R_{ns}(.05,192)=1.11 groups at Session 0 (baseline) and reliably higher mean IF scores than the RHSI (R_{ns}(.01,192)=1.47), LHVA (R_{ns}(n.001,192)=1.83), and RHVA (R_{ns}(.005,192)= 1.59) groups at Session 2. In addition, the RHSI (R_{ns}(.05,192)=1.14) and RHVA (R_{ns}(.01,192)=1.47) groups both displayed reliably higher mean IF scores during Session 0 (baseline) than the LHVA group. Finally, further analysis of a reliable Hemisphere x Cognitive Style interaction ($\underline{F}$(.05,1/12)= 6.01, MS_e=23.50) revealed that the LHSI group displayed reliably higher mean IF scores than the LHVA group ($\underline{t}$(.05,134)=2.18) when mean IF scores were averaged over all sessions.

These data indicate that the reliable EEG frequency difference found between SI and VA subjects in the resting state (e.g., SI $>$ VA) was mediated by the left hemisphere. Moreover, this left hemisphere frequency difference by cognitive style persisted through training, as well. The latter statement is supported by the frequency difference found between SI and VA subjects in the left hemisphere at each training session (see Figure 6)[16], and particularly, by the reliable frequency difference found between these

subjects when mean IF scores were averaged over all sessions. Further, it should be recalled that this particular frequency difference in the left hemisphere was found in the resting state where baseline data were analyzed in the absence of training data. Finally, as indicated, electrophysiological differences between SI and VA subjects in the resting state were not anticipated.

Further analysis of the Hemisphere x Cognitive Style x Sessions interaction revealed that the RHSI group reliably reduced its mean IF scores (from baseline) at Session 3 ($R_{ns}(.05,192)=1.14$), but displayed no reliable reductions relative to Session 3. On the other hand, the LHSI group reliably reduced its mean IF scores (from baseline) at Session 6 ($R_{ns}(.05,192)=1.11$) and again (from Session 6) at Session 15 ($R_{ns}(.05, 192)=1.13$). Finally, no reliable reductions (from baseline) were found at any session for the LHVA or RHVA groups. These data indicate that the RHSI and LHSI groups trained successfully, whereas the LHVA and RHVA groups did not (see Hypotheses 3 and 4). However, contrary to expectations, the LHSI group performed better in training than the RHSI group (see Hypothesis 5a).

Taken together, the findings presented above provide partial support for Hypothesis 5a and complete support for Hypotheses 5b, 5c, 6a, 6b, and 7. More specifically, SI subjects with right hemisphere-placed electrodes, as expected, reduced their EEG frequency at a greater rate than SI subjects with left hemisphere-placed electrodes (see Hypothesis 5a).[17] Also as expected, SI subjects with right hemisphere-placed electrodes reduced their EEG frequency to a greater degree and at a greater rate than VA subjects with either left or right hemisphere-placed electrodes (see Hypotheses 5b and 5c).

However, contrary to expectations, these findings indicate that SI subjects with left hemisphere-placed electrodes performed better in low arousal EEG training than all other groups. More specifically, these subjects reduced their EEG frequency to a greater degree than SI subjects with right hemisphere-placed electrodes (contrary to Hypothesis 5a). Consistent with expectations, however, SI subjects with left hemisphere-placed electrodes reduced their EEG frequency to a greater degree and at a greater rate than VA subjects with left hemisphere-placed electrodes (see Hypothesis 6a), and to a greater degree and at a greater rate than VA subjects with right hemisphere-placed electrodes (see Hypothesis 6b). Further, as predicted, VA subjects did not reliably reduce their EEG frequency during training (regardless of hemisphere electrode placement (see Hypothesis 7).

Finally, these data indicate that performance in low arousal EEG training was generally better when the feedback stimulus reflected activity from the left hemisphere. More specifically, with the exception of rapid (but transient) reductions in EEG frequency (cf. performance of RHSI group), greater performance in low arousal EEG training was associated with the spatial-intuitive cognitive mode along with electrode placement over the left (in this case, the "non-preferred") hemisphere. Therefore, contrary to expectations (see Chapter 1), the left hemisphere was found to be a more salient variable in low arousal EEG training among SI and VA subjects than either the right hemisphere or the descriptive distinction between the "preferred" vs. "non-preferred" hemisphere.

In order to determine whether EEG amplitude and alpha fluctuated across sessions along with trained frequency changes within the two hemispheres,

mean I_eA and AI scores for the LHSI, RHSI, LHVA, and RHVA groups were analyzed separately within independent 2 (Hemisphere) x 2 (Cognitive Style) x 16 (Sessions) analyses of variance with repeated measures. Mean I_eA and AI scores are compared graphically in Figures 8 and 9, respectively.

Figures 8 and 9 about here

No main effects or interactions with Sessions for Hemisphere or Cognitive Style were found in these analyses. In addition, no I_eA or AI baseline differences (other than those presented earlier) were found for these groups where baseline data were analyzed within the same matrix. However, reliable Hemisphere x Cognitive Style interactions were found for both the I_eA variable ($\underline{F}(.05,1/12)=4.81$, $MS_e=977.55$) and the AI variable ($\underline{F}(.05,1/12)=5.64$, $MS_e=6896.10$). Further analysis of these interactions revealed that the LHVA group displayed reliably higher mean I_eA scores than the LHSI ($\underline{t}(.05,134)=2.13$) and RHVA ($\underline{t}(.05,134)=2.12$) groups and reliably higher mean AI scores than the LHSI ($\underline{t}(.05,134)-2.18$) and RHVA ($\underline{t}(.05,134)-2.17$) groups when these variables were averaged over all sessions.

These findings lend further support to the EEG frequency, amplitude, and alpha differences in the left hemisphere reported earlier between SI and VA subjects when they were at rest (e.g., during baseline recording) and when they were "active" (e.g., during training). More specifically, it was reported earlier that, within the left hemisphere, SI subjects displayed higher frequency and less alpha than VA subjects during baseline recording, and higher frequency than VA subjects at each training session

(see footnote 16) and when all training sessions were averaged. In addition, it was reported that feedback from the left hemisphere resulted in greater frequency reductions during training than feedback from the right hemisphere.

The findings presented above augment those presented earlier by revealing that, within the left hemisphere, SI subjects displayed lower amplitude and less alpha than VA subjects when all training sessions were averaged. Finally, taken together, the baseline and training data presented throughout this chapter indicate that the electrophysiological activity of the left hemisphere played a major role in distinguishing SI and VA subjects during both resting and "active" experimental states.

High and low Es groups. In order to determine whether subjects found to be high in ego strength performed better in training than those found to be low in ego strength (see Hypothesis 2), mean IF and I_mA scores for each training session were statistically evaluated against their respective baseline means via per cent change measures. As with SI and VA subjects (disregarding feedback mode), scores reflecting per cent change from baseline for both high and low Es groups were analyzed within a 2 (Ego Strength) x 2 (Feedback Mode) x 16 (Sessions) analysis of variance with repeated measures.

A reliable Sessions effect ($\underline{F}(.001,15/420)=11.77$, $MS_e=669.63$) revealed that reductions in physiological activity occurred during training for these groups. However, no main effect or interactions with Feedback Mode or Sessions for the Ego Strength factor were found in this analysis. These findings indicate that high and low ego strength subjects did not differ in amount or rate of reduction of physiological activity across sessions. These specific components of Hypothesis 2 are thus unsupported.

No statistical analyses were performed to determine whether SI, VA, high Es, and low Es groups differed in performance during training. However, the analysis described above revealed that the high Es group reduced its physiological activity from baseline by 26%, while the low Es group reduced its activity by 22%. When these values are compared to similar performance values of the SI and VA groups (e.g., 25% vs. 22%, respectively), it can be seen that no reliable differences among SI, VA, high Es, and low Es groups existed. These data thus provide complete support for Hypothesis 3 and no support for Hypothesis 4.

Summary of Training Results

Since the hypotheses of the present study were primarily concerned with predicting differential performance in biofeedback training by cognitive style, a summary of training results is presented. Specifically, it will be asked: When all training data are considered, were the experimental hypotheses (cf. Chapter 1) largely supported or unsupported? In addition, were there any unexpected findings which played an important role in evaluating support for the hypotheses proposed? As a source of reference during this discussion, Table 3 presents the components of each training hypothesis, along with indication of its support or non-support, as provided by the training results of the present investigation.

Table 3 about here

It is apparent from the training data presented in Figure 3 that a major unexpected finding was the independent effect of a biofeedback task difficulty variable. That is, the data in Figure 3 indicate that low arousal EEG training was more difficult for the subjects than low arousal EMG training. More specifically, where feedback mode was dis-

regarded, SI and VA subjects did not differ as predicted (cf. Table 3, Hypothesis 1). Moreover, when the raw EMG training data were evaluated independently of the raw EEG data, an identical lack of differences between SI and VA subjects was found. Thus, when feedback mode was disregarded, or when data from the easier of the two tasks (e.g., EMG feedback training) were separately examined, no support for Hypothesis 1 was provided.

On the other hand, when training data from the more difficult of the two tasks (e.g., EEG feedback training) were separately examined, it became apparent that complete support for most related hypotheses was provided. For example, where hemisphere electrode placement was disregarded, SI subjects reduced their EEG frequency to a greater degree and at a greater rate during training than VA subjects. In particular, it was found that VA-EEG subjects failed to reduce their frequency from baseline during training. Complete support for Hypothesis 1, as far as performance in EEG training is concerned, was thus provided. Finally, although not included within a specific hypothesis, analyses of I_eA and AI scores revealed that EEG amplitude and alpha index did not fluctuate appropriately along with the frequency changes effected by SI subjects during training.

Additional but qualified support for the EEG hypotheses proposed in the present study was provided when electrode placement was considered. For example, SI subjects with right hemisphere electrode placement (i.e., over their "preferred" hemisphere) reduced their frequency at a greater rate than all other hemisphere training groups, as predicted (cf. Hypothesis 5a). However, the best training performance overall was displayed by SI subjects with left hemisphere electrode placement (i.e., over their "non-preferred" hemisphere), viz., greater amount of frequency

reduction than all other groups.

The latter findings, in view of the VA subjects' failure to reduce their frequency during training (regardless of hemisphere electrode placement), thus provide complete support for Hypotheses 5b, 5c, 6a, and 6b and partial support for Hypothesis 5a (cf. Table 3). Moreover, the finding that VA subjects with electrode placement over their left (i.e., "preferred") hemisphere displayed performance in training equal to that of VA subjects with right (i.e., "non-preferred") hemisphere electrode placement, provides complete support for Hypothesis 7. Finally, although EEG amplitude and alpha index did not fluctuate reliably across sessions along with frequency changes, SI subjects displayed consistently higher frequency, lower amplitude, and less alpha than VA subjects in the left hemisphere.

Taken together, these findings indicate that the left hemisphere played a central role in distinguishing SI from VA subjects in the present investigation. The distinction emphasized between the "preferred" vs. "non-preferred" hemispheres during training (cf. Chapter 1) was thus found to be secondary in importance to that of the left hemisphere. Finally, although not anticipated, baseline or resting differences (as well as training or active differences) between SI and VA subjects also appeared to be mediated by the left hemisphere.

Equally unanticipated, no differences were found between high vs. low Es groups during training (i.e., both trained reliably). Moreover, no training differences among SI, VA, high Es, and low Es subjects (where feedback mode was disregarded) were found. These findings thus provide complete support for Hypothesis 3 and no support for Hypothesis 2 or 4 (cf. Table 3).

In conclusion, when separately considering the components of each training hypothesis, it can be seen in Table 3 that complete support for 13 (i.e., 65%) of the 20 hypotheses tested was provided by the training results of the present study.

Intuitive-Analytic Measure and Ego Strength Scale (Post-Training)

Although the present study was concerned primarily with predicting performance in biofeedback training from cognitive preference measuring instruments, post-training changes on the IN-AN and Es measures (and determining whether such changes were attributable to the training process) were also of interest.

Descriptive data. Summarizing the variability in the posttest questionnaire scores, Table 4 presents the means and S.D.s of these

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Table 4 about here

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scores for the IN-AN and Es measures (and their respective change scores from pretest to posttest) for the Third Sample and all experimental training groups. As can be seen, IN-AN posttest scores for the Third Sample remained relatively extreme among groups distinguished by cognitive style, despite the presence of a reliable shift in the IN-AN distribution toward the intuitive mode from pretest to posttest ($t(.05,30)=2.30$). The Es measure remained relatively stable across training sessions, displaying no reliable changes from pretest to posttest for the Third Sample (disregarding group breakdowns).

Group data. No reliable differences were found among the experimental groups on the posttraining Es and Es change score measures. Disregarding feedback mode, however, it was found that VA trainees evidenced a reliable

increase in IN-AN scores (pre to post) (t(.01,15)=-3.23) and displayed reliably greater mean IN-AN change scores than SI trainees (t(.01,30)= 2.91). In addition, the VA-EEG group increased reliably on the IN-AN measure across training (t(.01,7)=-3.74) and also displayed reliably greater mean IN-AN change scores than the SI-EEG group (t(.01,14)=3.00).

Moreover, the RHVA group, evidencing the greatest mean pre-post increase on this measure than any other group (t(.05,3)=-2.57), displayed reliably greater mean IN-AN change scores than the LHSI group (t(.05,6)= 2.75). Further, the LHVA group, similarly increasing IN-AN posttest scores reliably (t(.001,2)=-10.06), also displayed a reliably greater change on this measure than the LHSI group (t(.01,6)=4.00). Finally, male trainees demonstrated a reliable increase in IN-AN posttest scores (t(.05,16)=-2.21), while females did not.

In general, these data indicate that reliable differences between pre- and post-training mean IN-AN scores were displayed exclusively by VA groups (with the exception of the sex finding) and were always in the direction of the intuitive mode.

Intuitive-Analytic Measure, Ego Strength Scale, and Biofeedback Training

Individual training. In addition to the group data presented for both biofeedback training and subsequent alterations on the IN-AN and Es measures, the subjects' performance during training was investigated more precisely in the hope of shedding additional light on the relationship between biofeedback training and the psychological measures used in this experiment. Specifically, in order to properly evaluate the role of cognitive style in successful biofeedback training (both as an independent and dependent variable), each trainee's mean IF or I_mA (i.e., feedback-

contingent) scores across sessions were statistically evaluated for reliability via multiple regression analyses and *t*-tests.

Where a reliable regression component and a reliable difference (via *t*-test) between the first two and last two sessions (i.e., Sessions 0 (baseline) and 1 *vs*. Sessions 15 and 16) or the first three and last three sessions (i.e., Sessions 0 (baseline), 1, and 2 *vs*. Sessions 14, 15, and 16) were found, successful training was said to have taken place. However, with reference to the previously-stated training definition, the absence of a reliable regression component in the presence of at least one reliable *t*-test as described above (or vice versa) served as the minimum criterion for successful individual training. In addition, multiple regression analyses and *t*-tests were performed in a similar manner on mean I_eA and AI scores in order to evaluate the reliability of their respective fluctuations across sessions for each EEG trainee.

Table 5 presents the results of these analyses according to the group

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Table 5 about here

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to which each trainee belongs. As can be seen, 22 of the 32 subjects (i.e., 69%) trained reliably, and did so in a manner consistent with the group data reported earlier. In addition, although the LHSI trainees more often displayed reliable fluctuations in mean I_eA and AI scores during training, changes in these values, overall, contributed little toward further differentiation of the various cognitive style groups.

Individual training and shifts in cognitive style. The more important reason for acquiring individual training data was to further reveal the relationship between successful biofeedback training and the subsequent

posttraining alterations reported on the questionnaires. Since the experimental groups who trained reliably always contained at least one trainee who did not, separating these subjects within certain analyses should allow a more powerful statement to be made concerning the independent effect of successful biofeedback training on cognitive style. Thus, the following question will be asked of these analyses: Did those subjects who trained successfully display the largest alterations on the IN-AN and Es measures, that is, were the questionnaire shifts attributable to the biofeedback training process or to other, perhaps nonspecific treatment effects?

Of the training groups themselves (see Table 4), it can be seen that those who trained reliably (e.g., SI-EMG, SI-EEG, LHSI, and RHSI groups) displayed negligible IN-AN changes, while those who did not train reliably (e.g., VA-EEG, LHVA, and RHVA groups) all displayed impressive (i.e., reliable) changes on this measure toward the intuitive mode. (The VA-EMG group was the only exception to this: These subjects trained reliably and changed (not reliably) toward the intuitive mode.) This distinction was found only on the IN-AN measure, as changes on the Es measure were negligible for all training groups.

On the basis of comparisons between individually trained vs. untrained subjects within each group, this finding became even more pronounced. Table 6 presents IN-AN and Es change score data for trained vs. untrained

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Table 6 about here

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subjects according to experimental groups. As can be seen, untrained subjects displayed greater IN-AN change scores than trained subjects in

21 of 23 group breakdowns (statistically reliable for female (EEG) ($\underline{t}(.01,4)=-7.00$) and low ego strength (EEG) ($\underline{t}(.01,5)=-5.66$ groups). Equally interesting, 21 of 23 group breakdowns displayed greater Es change scores for trained than for untrained subjects (statistically reliable for EEG ($\underline{t}(.05,14)=2.22$), high ego strength ($\underline{t}(.05,14)=2.15$), and low ego strength (EEG) ($\underline{t}(.01,5)=6.46$ groups).

Although these individually untrained vs. trained change scores differences were not statistically reliable in the majority of cases, the impressive consistency of the findings must be considered in their interpretation.

Correlational data. Primary to the present investigation was the differential ability of the psychological instruments to predict resting physiological activity, performance in biofeedback training, and subsequent shifts on these measures following training. Table 7 presents the correlation coefficients between the questionnaires and training variables for all experimental groups for whom these coefficients were reliable. As can be

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Table 7 about here

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seen, none of the questionnaire measures were related to EMG (i.e., I_mA) baseline or difference scores. However, IN-AN scores were negatively related to MxO scores, or scores reflecting each subject's "maximum drop" from baseline (i.e., per cent reduction of physiological activity from baseline relative to lowest daily average).

Specifically, IN-AN scores were negatively related to MxO scores for the SI-EMG group and positively related to MxO scores for the VA-EMG group, indicating that the largest EMG reductions from baseline were

effected by trainees with low IN scores (SI-EMG group) and low AN scores (VA-EMG group). In addition, V scores were positively related to MxD scores and S scores were negatively related to MxD scores for the SI-EMG group, indicating that the largest EMG reductions within this group were effected by trainees with relatively high V socres and low S scores.

With respect to the EEG variables, S and IN-AN scores correlated with IF and AI baseline scores more often than did V scores, while Es scores correlated only with I_eA baseline scores (RHSI group). In addition, IN-AN scores correlated with IF differences scores more often for groups who trained successfully, while V scores correlated with IF difference scores more often for groups which did not. Moreover, the IN-AN measure correlated with individual training, but only for one group (VA-EMG).

Integrating the direction and specificity of these correlations revealed that high IN, high V, and low S scores were related to high baseline frequency and the largest frequency difference scores, while low IN and low S scores were related to high baseline alpha. Finally, low Es scores were related to high baseline amplitude, while low AN scores were related to successful individual training.

With respect to questionnaire shifts following training (and consistent with the group data presented earlier), AN and low Es scores were related to IN-AN and Es change scores, respectively, for all trainees and most groups. In addition, low S scores and high V scores were related to IN-AN and Es change scores, respectively. (The exception to this was the VA-EMG group, where Es change scores were associated with low V scores.)

The final variable found to be related to the questionnaires was sex. Specifically, IN-AN scores were positively related to sex and Es scores were negatively related to sex, indicating that females were associated with intuitive thinking and low ego strength, while males were associated with

analytic thinking and high ego strength. (A more detailed discussion of the sex differences found in the present study is presented in Appendix F.)

Biofeedback Training: Dependent Variables

Table 7 also presents correlational data for the dependent training variables (e.g., I_mA, IF, I_eA, and AI baseline scores; I_mA and IF difference scores). As can be seen, baseline EMG amplitude and EEG frequency were positively related to EMG amplitude and EEG frequency difference scores, respectively, for most groups. Baseline frequency was also positively related to individual training for most groups, indicating that EEG subjects who trained successfully displayed higher baseline frequency than those who did not.[18]

In addition, baseline EMG amplitude (EMG group), baseline EEG frequency (EEG, LH groups), and baseline EEG amplitude (RHVA group) were positively related to sex, while baseline alpha (SI-EEG, LHSI groups) was negatively related to sex. These findings indicate that, for these groups, females displayed higher baseline frequency and amplitude (both EEG and EMG) than males, while males displayed higher baseline alpha than females.

Moreover, for most EEG groups, baseline frequency was negatively related to baseline alpha, while baseline amplitude was positively related to baseline alpha. Further, baseline frequency and alpha were positively related to hemisphere for two of the EEG groups, indicating that right hemisphere trainees displayed higher baseline frequency (VA-EEG group) and baseline alpha (SI-EEG group) than left hemisphere trainees. Finally, EMG amplitude (VA-EMG group) and EEG frequency difference scores were positively related to training. These findings indicate that, with the exception of resting frequency in the right hemisphere, EEG baseline frequency, amplitude, and alpha recorded in the present study were related in a manner consistent with current electrophysiological knowledge (cf. Craib and Perry, 1975).

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Introduction

The results of the present investigation provide complete or partial support for all but three of the hypotheses tested. For example, complete support (i.e., differential amounts and rates of training, as predicted) is demonstrated for Hypotheses 3, 5b, 5c, 6a, 6b, and 7, while partial support (i.e., differential amounts or rates, as predicted) is demonstrated for Hypothesis 5a. Only Hypotheses 1, 2, and 4 remain unsupported (see Chapter 3, Table 3).

While the cognitive preference measuring instruments are apparently isolating different cognitive-perceptual variables, they nevertheless combine to predict portions of the expected group differences in performance during low arousal biofeedback training. This is particularly true in EEG training, where the biofeedback task is relatively more difficult than in EMG training. Moreover, although differently than expected, hemisphere electrode placement also appears to be effective as a predictor of performance in EEG training. Thus, although with necessary qualification, performance in low arousal biofeedback training is associated with the cognitive styles (and, to a certain extent, the hemisphere electrode placements) suggested in Chapter 1.

Since performance differentials associated with cognitive style factors were found primarily among EEG subjects, discussion and interpretation of these results will be the central focus of this Chapter. (Factors underlying successful biofeedback training, task difficulty, and electrophysiological

correlates of the biofeedback task in the present investigation are discussed in Appendix D.)

Cognitive Preference Instruments and Ego Strength Scale: Predictability

Intuitive-analytic measure. A central question in the present investigation concerns the relative ability of each cognitive diagnostic questionnaire to predict performance in biofeedback training. Inspection of the correlational data in Table 7 indicates that Baumgardner's Intuitive-Analytic measure best predicted success in training, followed by Galin and Ornstein's Spatial-Verbal measure and Barron's Ego Strength Scale, respectively.

Although no previous research along this line has been conducted with the Intuitive-Analytic measure, other investigators have recently reported reliable predictability of feedback training performance as a function of the cognitive strategies employed by their subjects (e.g., Spencer, Dale, Blankstein & Anderson, 1976). In addition, Rotter's (1966) I-E scale has been investigated as a predictor of success in training. Specifically, internals were found to be better than externals in controlling frontalis EMG (Fotopoulos & Binegar, 1976; Reinking, Morgret & Tamayo, 1976), EEG alpha (Fotopoulos & Binegar, 1976), and heart rate (Lyon, Blankstein, Darte & Dale 1976).

While Rotter's scale represents a generalized expectancy for internal vs. external control of reinforcement (Levy, 1970), Baumgardner's measure stems from a developmental perspective in which individuals are thought to progress from a relatively primitive, global cognitive orientation (e.g., intuitive mode) to a more differentiated one (e.g., analytic mode) (Baumgardner, 1973; Quinn, 1975). However, in view of the intuitive appeal of the findings reported with Rotter's scale, it would appear useful to acquire correlational data between these questionnaires in the future in order to determine whether they are, in fact, measuring different cognitive dimensions.

Spatial-verbal measure. A paradoxical but interesting result of the present study concerns the finding that verbal scores on Galin and Ornstein's (1974) measure were associated with success in low arousal training while spatial scores were not (see Table 7). Since this finding lends further support to the idea that the left hemisphere played a role in the training process, discussion of this point is warranted.

Inspection of the verbal and spatial score distributions in Table 1 (along with the above finding) provides some basis for hypothesizing a culturally-mediated role for the left hemisphere in low arousal biofeedback training. Specifically, the distribution of verbal-spatial scores for the Second Sample (n=195) was heavily skewed in the verbal direction (i.e., toward left hemisphere activity), resulting in a disproportionately large number of "verbal responders" and very few "spatial responders."

Assuming minimal error of measurement any explanation of this skewed distribution (as well as verbal scores' higher association with performance) would seem relevant to our strong cultural reinforcement of verbal-analytic behavior and relative indifference toward spatial-intuitive behavior. The most basic example of such selective reinforcement can be seen in the small number of artistic-holistic vocations in our culture relative to logico-rational ones. Consequently, obtaining a homogenous sample of "spatial responders" would appear to require careful systematic sampling within Western culture, particularly within a university setting.

Cultural facilitators of a relatively differentiated cognitive mode have been reviewed by Nash (1970) and include early academic influences (Kagan, Rosman, Day, Albert & Phillips, 1964), child rearing practices (Shaffer, Mednick & Seder, 1957; Witkin, 1967) and person-environment interactions (Dawson, 1963; Berry, 1966).

However, a more relevant example of this cultural influence is illustrated in a recent investigation by Davidson and Schwartz (1976). In two independent studies, these researchers found that non-musically trained subjects displayed the well-documented EEG lateral asymmetry effect when whistling a song (right hemisphere task) vs. speaking the lyrics (left hemisphere task), whereas musically trained subjects did not. More specifically, non-musically trained subjects displayed reliably greater right hemisphere activation during the whistling task than musically trained subjects.

Thus, formal (i.e., academic) musical training was found to be associated with the adoption and reinforcement of an analytic-sequential processing mode toward melodic information, the processing of which has long been considered a "pure" right hemisphere task. Finally, these results suggested to the author that long term training in complex skills has functional neural concomitants.

Along this line, support for the hypothesis of a culturally-mediated effect of the left hemisphere during low arousal training would thus appear to require consonant electrophysiological data, viz., left hemisphere activity in the relative absence of right hemisphere activity. However, as indicated in Appendix D, Section 3, the relatively divergent electrophysiological activity which occurred during training in the present study supports the hypothesis that low arousal biofeedback training was mediated primarily by the right hemisphere. Moreover, the split-brain work of Galin (1974) and the work of Greenstadt, Schuman & Shapiro (1976), who found that left hemisphere activity (via right monaural feedback) was superior to right hemisphere activity (via left monaural feedback) in high arousal heart rate training, also supports this hypothesis.

Thus, the finding that verbal scores predicted success in low arousal training better than spatial scores requires an alternative explanation, since no electrophysiological evidence exists in support of a culturally-

mediated role for the left hemisphere. Such an explanation should, in the interest of methodology, focus upon the measuring instrument itself.

Since spatial processing has been linked to the right hemisphere and the right hemisphere to low arousal biofeedback training, the functional adequacy of the Spatial-Verbal measure for the present investigation requires evaluation. Specifically, the measure must meet two related criteria: (1) It must sufficiently dichotomize "verbal responders" and "spatial responders" such that (2) with bilateral recordings, reliable lateral asymmetry is discernible interhemispherically during the administration of the task.

In this connection, although Hasset and Zelner (1976) found that Galin and Ornstein's Word-Shape Preference Test produced a more robust lateral asymmetry in subjects than an emotional-nonemotional measure, the absence of bilateral recordings in the present study renders electrophysiological support inconclusive.

However, examination of the spatial-verbal distributions obtained by Galin and Ornstein themsleves reveals a critical difference to that obtained within the present study. As a measure of the task's ability to dichotomize "verbal responders" and "spatial responders," the average verbal/spatial ratio for their 35 occupationally-matched subjects was 3.5. Broken down by occupation, the ceramicists displayed a verbal/spatial ratio of 1.57 and lawyers a ratio of 17.00. In contrast, these ratios for the present study were 4.04 (all trainees), 2.78 (Intuitives), and 6.56 (Analytics).

These differences in verbal/spatial ratios indicate that (1) greater separation between "verbal responders" and "spatial responders" was apparent in Galin and Ornstein's (1974) study, and (2) the occupationally-matched subjects in their study displayed greater laterality of hemisphere preference than the present study's subjects selected on the basis of Intuitive-Analytic test scores.

Thus, in Galin and Ornstein's study, the use of the Spatial-Verbal measure served as a successful validation procedure, ensuring that ceramicists preferred the use of their right hemisphere and lawyers their left. In the present study, however, such validation of intuitive vs. analytic subjects proved to be equivocal, particularly in view of the lack of correlation found between the Intuitive-Analytic and Spatial-Verbal measures.

Further, in view of the differences found between Galin and Ornstein's and the present study in both subject selection and dispersion of spatial-verbal scores, it is apparent that assumptions concerning relative right vs. left hemisphere preference by cognitive style are less likely to be violated where extreme, occupationally-matched groups of subjects are employed (i.e., systematic sampling), as compared to groups selected from a random sample via questionnaire on the basis of generalized cognitive strategies.

Finally, while it is tempting to invoke cultural influencers in this instance, or to conclude that spatial processing is not as important during successful low arousal training as generalized cognitive strategies, or even verbal processing, such statements appear premature based on relevant interpretation of available evidence. That is, although the left hemisphere is apparently involved in the low arousal EEG training process (cf. baseline and training differences between LHSI and LHVA groups; see Chapter 3), its precise role is as yet unclear. Consequently, the paradoxical correlations found between verbal scores and success in training are best interpreted cautiously (e.g., attributed to imprecise subject selection and measurement) until additional data become available.

Ego strength scale. The finding of no differences in training between high vs. low ego strength subjects is not easily explained. In view of recent studies which lend further support to the relationship between ego strength

and physiological responsiveness (e.g., Boudewyns & Levis, 1976; Neary & Zuckerman, 1976), the proposal of Hardt (1975) that high ego strength subjects should perform better in training than low ego strength subjects remains quite plausible.

One alternative explanation for this negative finding concerns the possible interaction between ego strength and anxiety level in the subjects. Since high anxiety levels have been negatively correlated with physiological responsiveness (Roessler, 1973; Lader & Wing, 1966), high ego strength-high anxiety subjects and low ego strength-low anxiety subjects should not differ in physiological responsiveness (Neary & Zuckerman, 1976) and thus, they should not differ in performance during biofeedback training. However, since no measures of anxiety were taken in the present study, this explanation cannot be verified.

An additional explanation considers that, while some correlations between ego strength and responsiveness of central nervous processes have been reported, changes in skin conductance, autonomic nervous system process, have correlated most often with ego strength (Roessler, 1973). Thus, the centrally-mediated processes trained in the present investigation may not have been as sensitive to (i.e., reflective of) differences in ego strength as autonomically-mediated processes would have been.

Moreover, the present study in its method makes an inherent distinction between "responsiveness" and "controllability" of a physiological process. While these two concepts may be related, to the author's knowledge no evidence exists to support their being used interchangably. For example, while the responsiveness of a physiological process may involve an interaction between coping ability and nervous system mediation, the controllability of that process may involve primarily cognitive variables, as suggested in the present investigation.

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Since spatial processing has been linked to the right hemisphere and the right hemisphere to low arousal biofeedback training, the functional adequacy of the Spatial-Verbal measure for the present investigation requires evaluation. Specifically, the measure must meet two related criteria: (1) It must sufficiently dichotomize "verbal responders" and "spatial responders" such that (2) with bilateral recordings, reliable lateral asymmetry is discernible interhemispherically during the administration of the task.

In this connection, although Hasset and Zelner (1976) found that Galin and Ornstein's Word-Shape Preference Test produced a more robust lateral asymmetry in subjects than an emotional-nonemotional measure, the absence of bilateral recordings in the present study renders electrophysiological support inconclusive.

However, examination of the spatial-verbal distributions obtained by Galin and Ornstein themsleves reveals a critical difference to that obtained within the present study. As a measure of the task's ability to dichotomize "verbal responders" and "spatial responders," the average verbal/spatial ratio for their 35 occupationally-matched subjects was 3.5. Broken down by occupation, the ceramicists displayed a verbal/spatial ratio of 1.57 and lawyers a ratio of 17.00. In contrast, these ratios for the present study were 4.04 (all trainees), 2.78 (Intuitives), and 6.56 (Analytics).

These differences in verbal/spatial ratios indicate that (1) greater separation between "verbal responders" and "spatial responders" was apparent in Galin and Ornstein's (1974) study, and (2) the occupationally-matched subjects in their study displayed greater laterality of hemisphere preference than the present study's subjects selected on the basis of Intuitive-Analytic test scores.

Thus, in Galin and Ornstein's study, the use of the Spatial-Verbal measure served as a successful validation procedure, ensuring that ceramicists preferred the use of their right hemisphere and lawyers their left. In the present study, however, such validation of intuitive vs. analytic subjects proved to be equivocal, particularly in view of the lack of correlation found between the Intuitive-Analytic and Spatial-Verbal measures.

Further, in view of the differences found between Galin and Ornstein's and the present study in both subject selection and dispersion of spatial-verbal scores, it is apparent that assumptions concerning relative right vs. left hemisphere preference by cognitive style are less likely to be violated where extreme, occupationally-matched groups of subjects are employed (i.e., systematic sampling), as compared to groups selected from a random sample via questionnaire on the basis of generalized cognitive strategies.

Finally, while it is tempting to invoke cultural influencers in this instance, or to conclude that spatial processing is not as important during successful low arousal training as generalized cognitive strategies, or even verbal processing, such statements appear premature based on relevant interpretation of available evidence. That is, although the left hemisphere is apparently involved in the low arousal EEG training process (cf. baseline and training differences between LHSI and LHVA groups; see Chapter 3), its precise role is as yet unclear. Consequently, the paradoxical correlations found between verbal scores and success in training are best interpreted cautiously (e.g., attributed to imprecise subject selection and measurement) until additional data become available.

Ego strength scale. The finding of no differences in training between high vs. low ego strength subjects is not easily explained. In view of recent studies which lend further support to the relationship between ego strength

and physiological responsiveness (e.g., Boudewyns & Levis, 1976; Neary & Zuckerman, 1976), the proposal of Hardt (1975) that high ego strength subjects should perform better in training than low ego strength subjects remains quite plausible.

One alternative explanation for this negative finding concerns the possible interaction between ego strength and anxiety level in the subjects. Since high anxiety levels have been negatively correlated with physiological responsiveness (Roessler, 1973; Lader & Wing, 1966), high ego strength-high anxiety subjects and low ego strength-low anxiety subjects should not differ in physiological responsiveness (Neary & Zuckerman, 1976) and thus, they should not differ in performance during biofeedback training. However, since no measures of anxiety were taken in the present study, this explanation cannot be verified.

An additional explanation considers that, while some correlations between ego strength and responsiveness of central nervous processes have been reported, changes in skin conductance, autonomic nervous system process, have correlated most often with ego strength (Roessler, 1973). Thus, the centrally-mediated processes trained in the present investigation may not have been as sensitive to (i.e., reflective of) differences in ego strength as autonomically-mediated processes would have been.

Moreover, the present study in its method makes an inherent distinction between "responsiveness" and "controllability" of a physiological process. While these two concepts may be related, to the author's knowledge no evidence exists to support their being used interchangably. For example, while the responsiveness of a physiological process may involve an interaction between coping ability and nervous system mediation, the controllability of that process may involve primarily cognitive variables, as suggested in the present investigation.

Finally, it should be recalled that the ego strength subjects used in the present study were also either SI or VA subjects. As such, the high _vs_. low ego strength samples were contaminated by the distribution of SI and VA tendencies among them. In view of the association found between low ego strength and high intuitive/low analytic thinking (and thus high ego strength and high analytic/low intuitive thinking) (see Chapter 3), training differences between high _vs_. low ego strength groups should perhaps not have been anticipated.

Thus, until the roles of anxiety, nervous system mediation, and controllability (_vs_. responsiveness) are systematically examined in relation to uncontaminated high _vs_. low ego strength samples, no meaningful statements about the relationship between ego strength and performance in low arousal biofeedback training can be made.

Intuitive-Analytic Measure and Ego Strength Scale: Post-Training Changes

Intuitive-analytic measure. With regard to post-training effects, the reliable changes toward the intuitive mode on the Intuitive-Analytic measure displayed by most subjects who failed to train successfully deserve mention. Since these subjects did not display either reductions in physiological activity or post-training changes on the Ego Strength scale, it can only be surmised that they attempted to justify their many hours of time and effort spent in the laboratory via socially desirable changes on the Intuitive-Analytic measure. This finding is consistent with a study by Plotkin, Maxer and Loewy (1976), who report that the occurrence of an "alpha experience" in their subjects was negatively correlated with performance in alpha enhancement training.

Taken together, these results suggest that subjects volunteering for biofeedback experiments may have preconceived ideas about what should occur during and/or following the experiment. For example, Plotkin's et al. subjects experienced pleasurable subjective feelings not as a function of self-regulated

physiology, but as a function, perhaps, of expectations related to popular myths concerning the alpha rhythm currently circulating among "students" of altered states of consciousness. Along the same line, unsuccessful trainees in the present study may also have acted on expectations, displaying their "biofeedback experience" through heightened consideration of emotions or "gut feelings," as elicited by intuitively-oriented questions.

Ego strength scale. Another interesting result concerns post-training changes in ego strength. Specifically, the cognitive preference instrument which best predicted performance in training (e.g., Intuitive-Analytic measure) remained unchanged following training as a function of success, while the personality measure which failed to predict performance in training (e.g., Ego Strength Scale) displayed consistent, positive changes as a function of success. This was particularly true (i.e., statistically reliable) within EEG training, the more difficult of the two tasks, and among high ego strength subjects, in general.

In view of the lack of correlation found between intuitive-analytic and ego strength scores, it can be argued that the cognitive requisites for low arousal training appear to be maintained by the intuitive person, while treatment effects attributable to success in training are more likely to be displayed by intuitive individuals via changes in their ego strength scores. More specifically, while the Intuitive-Analytic measure elicits relatively enduring, more generalized cognitive strategies useful for predicting success in training, the content of the Ego Strength Scale appears to be more appropriate as a behavioral measure of treatment effect following training.

Thus, within a relatively difficult biofeedback task, it appears that coping ability (as measured by ego strength) will be enhanced by those who are successful at physiological control.

This finding concurs indirectly with those of Cox, Freundlich and Meyer (1976), who found reliable shifts toward internality (see Rotter, 1966) displayed by three of their feedback training groups. Also relevant indirectly, right hemisphere functioning (e.g., tonal memory and spatial localization) was enhanced following regular practice of Transcendental Meditation (Frumkin & Pagano, 1976; Harrison, Warrenburg & Pagano, 1976). Finally, clinical biofeedback training was found to produce reliably fewer somatic complaints among high _vs_. low ego strength patients (Lynch & Lynch, 1973).

Taken together, these findings suggest that the acquisition of low arousal physiological responses can result in measurably greater coping ability, as defined by ego strength scores. Moreover, the regular practice of low arousal techniques such as biofeedback training or meditation might allow individuals to preferentially effect a more balanced activation of the two cerebral hemispheres. This might be particularly useful where individuals manifest non-organic deficiencies in right hemisphere functioning.

Hemisphere Training and Laterality

Baseline activity. As indicated in Chapter 3, resting differences between SI and VA subjects were not specifically included within the experimental hypotheses presented in Chapter 1. The rationale for this exclusion is based primarily on the electrophysiological evidence reviewed in Appendix B, Scetion 3, which suggested that differences among subjects counterposed in cognitive style are less likely to be reliable during resting activity than during task-related or "active" activity (cf. Galin & Ornstein, 1972, 1974; Orstein & Galin 1973). In spite of this, reliable differences in EEG frequency (SI > VA), amplitude (SI < VA), and alpha (SI < VA) were found among these subjects during resting activity. Moreover, these baseline differences

are electrophysiologically consistent, they were found exclusively within the left hemisphere, and they persisted across EEG training sessions, as well (see Chapter 3).

However, these resting, electrophysiological differences by cognitive style are somewhat counterintuitive. More specifically, when the requisites for activation of the left and right hemispheres are considered separately, the opposite EEG pattern to that found would be expected. That is, assuming that activation of the preferred cognitive mode results in increased cerebration within the hemisphere functionally aligned with that mode, VA subjects might be expected to display higher frequency, lower amplitude, and less alpha than SI subjects,particularly within the left hemisphere. Although the baseline differences actually found could be the result of a sampling (i.e., alpha) error, the utility of such an attribution would appear questionable in view of (1) the absence of any firm basis for postulating resting differences by cognitive style (cf. Appendix B, Section 3), and (2) the presence of support for the EEG training hypotheses put forth by and tested in the present investigation (cf. Chapter 1).

Thus, although resting EEG differences by cognitive style are generally not viewed with the same importance as active (i.e., training) differences (cf. Orstein & Galin, 1973, 1975), and despite the counterintuitive nature of the resting differences found in the present study, these data nevertheless suggest that the left hemisphere is more sensitive to (i.e., reflective of) individual differences in electrophysiological activity by cognitive style than the right hemisphere.

These findings and their interpretation concur with those of Ornstein and Galin (1973, 1975) who reported that lateral asymmetry by cognitive style is more often caused by amplitude shifts in the left hemisphere than in the right,

Specifically, lawyers (i.e., subjects within a "left hemisphere" occupation) displayed laterality via reliably greater amplitude shifts in their left hemisphere than ceramicists (i.e., subjects within a "right hemisphere" occupation). Finally, although Patterson (1975) found that intuitive subjects displayed laterality via right hemisphere amplitude shifts and analytic subjects via left hemisphere amplitude shifts, he did not compare the relative degree of these shifts statistically. Thus, EEG laterality in his subjects may have been more often or to a greater degree mediated by the left hemisphere than the right, despite the occurrence of some right hemisphere-mediated laterality among intuitive subjects.

In conclusion, the activity of the left hemisphere has been implicated both as a predictor of an individual's preferred cognitive mode (i.e., in the resting state) and as a predictor of performance in low arousal EEG biofeedback training (i.e., in the active state). That is, despite the apparent task mediation displayed by the right hemisphere, the left hemisphere appears to have played a more complex role during dominant frequency reduction than was originally hypothesized.

Biofeedback training. In general, predictions regarding differential hemisphere training by cognitive style were supported. However, the hypothesis that spatial-intuitive subjects training from their right (i.e., "preferred") hemisphere would reduce their dominant frequency to a greater degree and more rapidly than similar subjects training from their left (i.e., "non-preferred") hemisphere (e.g., Hypothesis 5a), was only partially supported. Specifically, right hemisphere spatial-intuitive subjects reduced their dominant frequency from baseline at a greater rate, as predicted, but left hemisphere spatial-intuitive subjects trained to a reliably greater degree.

Thus, in addition to reflecting reliable baseline and averaged training

differences in frequency, amplitude, and alpha by cognitive style, the left hemisphere facilitated frequency decrements among subjects with cognitive styles counterposed to its lateralized function.

A rationale for the unexpectedly effective role of the left hemisphere during EEG training in the present study is now offered. Specifically, the following questions are asked in this regard: In view of the fact that spatial-intuitive subjects consistently performed as predicted in low arousal EEG training, why was their "preferred" hemisphere superior to their "non-preferred" hemisphere for rate of training, but not for amount of training? Or, conversely, why did these subjects' "non-preferred" hemisphere become "preferred" only when training for degree of dominant frequency reduction?

Any explanation for such "hemispheric transfer" must take the specific nature of the low arousal EEG biofeedback task used in the present study into consideration. Specifically, it can be argued that a conflict existed between the goals of the EEG task for right hemisphere spatial-intuitive subjects (i.e., right hemisphere frequency decrement) and the hemispheric mediation apparently required for such a task (i.e., right hemisphere activation, viz., amplitude and alpha decrement with concomitant frequency increment). In other words, right hemisphere spatial-intuitive subjects were asked to decrease their right hemisphere frequency, since this was the primary goal of the task, but were simultaneously required to increase their right hemisphere frequency, since low arousal biofeedback training apparently requires right hemisphere mediation.

This view is supported by the relative decrease in amplitude and alpha found in the right hemisphere of spatial-intuitive subjects training from their right hemisphere (see Figures 8 and 9). In addition, this conflict between the task goal and its apparent electrophysiological requisite could explain why frequency and amplitude (and thus, frequency and alpha) failed

to relate in a reliably inverse fashion within the right hemisphere for these subjects.

Thus, in view of these intrahemispheric competing responses, a relative deficiency in task performance would be expected by the right hemisphere groups. This deficiency is reflected in the training data of the present study: While right hemisphere verbal-analytic subjects failed to train successfully due to inappropriate cognitive style and hemisphere, right hemisphere spatial-intuitive subjects, maintaining the appropriate cognitive style, failed to reduce their dominant frequency beyond an initial, relatively rapid decrement at Session 3.

In this connection, left hemisphere spatial-intuitive subjects, who reduced their dominant frequency to a greater degree but at a lesser rate than right hemisphere spatial-intuitive subjects, might have done so for two reasons. First, since it was demonstrated that cognitive style outweighed hemisphere electrode placement in terms of performance in training (i.e., spatial-intuitive groups trained successfully and verbal-analytic groups did not, regardless of hemisphere electrode placement), it can reasonably be assumed that alternative physiological mechanisms to right hemisphere mediation, viz., left hemisphere inhibition, might be utilized by spatial-intuitive subjects in the interest of enhanced task performance.

Second, since feedback from the left hemisphere provides functional information concerning its activity level, which could then be used to facilitate left hemisphere inhibition, spatial-intuitive subjects might be expected to display greater amounts of frequency reduction when training from this hemisphere than from the right.

In other words, movement toward generalized low arousal should be facilitated by left hemisphere inhibition and would thus tend to result in

frequency decrements within the right hemisphere. Therefore, where right hemisphere spatial-intuitive subjects face an intrahemispheric conflict within their "preferred" hemisphere, reducing right hemisphere frequency by decreasing "mental chatter" or similar verbal-analytic interference via left hemisphere inhibition would appear to be an efficient alternative strategy to "overriding" such interference via right hemisphere mediation. In fact, reducing right hemisphere frequency without contralateral hemisphere inhibition would appear to be an unlikely occurrence.

Specifically in reference to the latter point, such a possibility cannot be ruled out. That is, consistent with the brain's capacity for extreme response specificity (see Schwartz, 1975), right hemisphere frequency decrement at O_8-T_4 could have been mediated via right hemisphere increment at alternative intrahemispheric sites (e.g., parietal or central cortex). However, in line with the "interference hypothesis" put forth by Ornstein and Galin (1973) this approach would appear to be less efficient than (i.e., unlikely to occur in the absence of) concomitant left hemisphere inhibition.

Moreover, in the absence of this intrahemispheric conflict (i.e., with left hemisphere feedback), reductions in left hemisphere frequency by spatial-intuitive subjects should be more pervasive than reductions in right hemisphere frequency. That is, while the "preferred" hemisphere may facilitate an initial reduction of frequency via (primarily) concomitant reductions of left hemisphere interference, there would appear to be a limit to the extent of this functional inhibition in the absence of left hemisphere feedback.

Thus, the role of left hemisphere feedback becomes important for spatial-intuitive subjects insofar as the performance of the right hemisphere (in right hemisphere frequency reduction) is confounded by the demands of the task. Specifically, it is proposed that following a period of initial frequency decrement, during which contralateral interference was apparently inhibited,

right hemisphere spatial-intuitive subjects found additional reduction impossible without feedback concerning left hemisphere activity. This can be seen in the single reliable frequency decrement from baseline at Session 3 for these subjects, as well as the greater instability of their learning curve (see Figure 6). In addition, the successful utlization of left hemisphere feedback, which simultaneously inhibits verbal-analytic interference while meeting the demands of the task, can be seen in left hemisphere spatial-intuitive subjects' reliable frequency reduction as Sessions 6 and 15, as well as their relatively stable learning curve (same Figure).

Finally, results indicate that inhibition of the left hemisphere without left hemisphere feedback was insufficient to enable right hemisphere spatial-intuitive subjects to progress in training beyond Session 3. However, the question of whether these subjects did, in fact, inhibit their left hemispheres during the early stages of training can not be unequivocally answered, since bilateral EEG recording was not employed in the present investigation.

In summary, it appears that dominant frequency reduction by spatial-intuitive subjects within their "preferred" right hemisphere is, with the exception of the early stages of training, confounded by the electrophysiological requisite in that hemisphere for low arousal training. While the apparent inhibition of left hemisphere activity facilitates a rapid, temporary decrease in right hemisphere frequency, as originally predicted, it is hypothesized that further decreases in frequency by these subjects can only be effected through additional inhibition of left hemisphere activity, viz., where feedback reflecting ongoing left hemisphere activity is provided.

Consequently, with the exception of a rapid, initial frequency decrement, the more functional cerebral hemisphere in these subjects for both pervasive and stable frequency reduction appears to be their left or "non-preferred"

one, regardless of within which hemisphere these decrements are desired.

Empirical support for this rationale could be provided by a replication of the present study where the utilization of bilateral EEG recording during both baseline and training sessions revealed interhemispheric relationships consonant with those described above. In addition, independent recordings from homologous leads over a variety of scalp locations (e.g., frontal, central, temporal, parietal, and occipital) would be preferable to the present study's usage of temporo-occipital leads recorded in a bipolar fashion. This would permit examination of intrahemispheric relationships during baseline and training sessions, as well.

Finally, any further study of this particular question should attempt to evaluate the interaction between the left hemisphere in dominant frequency reduction and the provision of verbal feedback throughout each training session. Although subjects in the present study reported that both auditory and verbal feedback were useful during training, the relative utility of each in relation to differential hemisphere activity during training was not systematically investigated.

Indirect support for the rationale presented above is provided in Natani (1976), who found that the right hemisphere of his subjects required fewer trials than the left to learn a color-form, size-form optional shift task. More important, Natani found that mediation by the left hemisphere augmented the abstractive ability of the right during this task, which was previously viewed as "strictly" right hemisphere-mediated.

Moreover, Ornstein and Galin (1973) and Orstein (1973) have developed a feedback technique which could help clarify the relationship between cognitive style and inter/intrahemispheric EEG controllability and cognitive specialization. Specifically, the integrated output of each EEG channel (e.g.,

homologous parietal leads) controls the loudness of a tone which is fed to the contralateral ear of the subject. The resulting binaural feedback gives a spatial illusion, with the sound appearing to move from the center to the left or right as the right/left ratio of parietal leads goes over or under one. Given this information, subjects are asked to "make the sound loud and move it to the left" or to the right.

All subjects tested with this feedback technique were able to alter their asymmetry index and, more important, the "mental gymnastics" used to control parietal asymmetry were not effective for controlling temporal asymmetry. Thus, in addition to measuring relative ability of EEG asymmetry induction, which would be useful for investigating individual difference variables, this technique appears to be sensitive to intrahemispheric specialization for cognition, as well.

Finally, while the rationale above for the results of the present study accounts for left _vs_. right hemisphere training differences among spatial-intuitive subjects, it does not explain the reliable baseline and averaged training differences in frequency, amplitude, and alpha found between spatial-intuitive and verbal-analytic subjects within the left hemisphere. Since these resting differences are counterintuitive as indicated, they pose some interpretive problems for the training results of the present study. These problems are discussed in Appendix E.

Theoretical Discussion

Returning to the specific interaction between cognitive style and low arousal biofeedback training, the question may again be asked: What is being learned by the subject during training and, based on available evidence, what role does his cognitive/emotional activity play in the training process?

As indicated, it has been assumed in the present study that the conditioning of a passive set resembling spatial-intuitive thinking is occurring during training. Although no comprehensive theories developing out of controlled systematic work now exist in this area (cf. Green & Green, 1975; Pribram, 1975; Turner, 1975), Schwartz (1975) has proposed a skeletal framework for such a theory, along with some supporting evidence. Schwartz's (1975) rationale,currently being investigated within a number of laboratories, will now be summarized and briefly discussed in view of the results of the present study.

Schwartz maintains that cognition and subjective experience are a direct result of _patterns_ of physiological activity, yet a reciprocal relationship between cognition/emotion and physiological patterning is apparently maintained by the human organism. Thus, according to this formulation, thoughts, images, and emotions are not only a product of underlying patterns of physiological processes, but they can induce such patterns, as well.

This principle is indirectly supported by Lazarus (1976), who places clinical biofeedback training in the larger context of adaptation and emotion. Specifically, he states that (1) emotional processes and their self-regulation are products of mediating cognitive appraisals about the significance of an event for a person's well-being, and (2) the control of somatic processes is an integral aspect of emotional states and their self-regulation.

Schwartz (1975) presents evidence to support his principle, in general, and Izard's (1971) neurophysiological theory of emotion, in particular. Izard's theory postulates that discrete patterns of facial and postural muscle activity are processed in parellel and integrated by the brain, and that they make up a significant component of the conscious experience of emotion. Extending this concept to self-regulated imagery, Schwartz, Fair, Greenberg,

Freedman and Klerman (1974) have demonstrated that small but discrete patterns of facial muscle activity are reliably generated when a person thinks about prior emotional experiences. In addition, cognitive/emotional states were found to be associated with identifiable covert facial expressions that were not recognizable by either observers or the subject himself (Schwartz, Fair, Salt, Mandel & Klerman, 1976).

This work supports the view that specific, self-induced cognitive states can generate discrete, predictable bodily patterns and that these somatic patterns may serve as a major physiological mechanism allowing imagery to elicit the cognitive/subjective experience associated with different emotions (Schwartz, 1975).

Much of the hemisphere work presented and discussed here is cited by Schwartz to further illustrate how self-regulated cognitive processes are associated with discrete patterns of physiological activity. He concludes that while control of <u>individual</u> physiological processes may not have identifiable cognitive referents, certain self-regulated <u>patterns</u> of multi-system activity do have such correlates, and when a person generates those cognitive/emotional patterns, he is also regulating their associated physiological patterns.

In this connection, the failure of most EEG biofeedback techniques to induce cognitive/emotional states similar to those reported by mediatators probably relates to the difference in process between the two techniques. Specifically, it is unreasonable to assume, simply because low frequency EEG activity occurs during mediatators that the voluntary control of a single physiological function (e.g., low frequency EEG) will produce the same cognitive/emotional response as the control of a number of patterned physiological functions, as is done by the experienced meditator. Thus, single

system biofeedback training is prone to emphasize specificity rather than patterning (Schwartz, 1975).

In support of this view, Schwartz (1976) found that lowering both blood pressure and heart rate produced greater subjective relaxation than lowering either alone. Similar results were obtained when subjects increased occipital alpha and lowered heart rate simultaneously vs. controlling either alone (Hassett & Schwartz, 1975).

Thus, according to this model, deep physiological relaxation and its cognitive/emotional concomitants are more likely to occur when a number of physiological processes are altered toward low arousal than the alteration of any one of them alone. Reciprocally, then, cognitive/emotional experiences emerging under these conditions should be more clearly identifiable and reinforcing of such patterned activity than experiences generated during the alteration of a single physiological system.

> Although it is not new, with few exceptions (the concept of emergent property) is still ignored. Neuropsychologists concerned with the biology of consciousness employ the same idea when they speak of cell assemblies (Hebb, 1974), neural engrams (John, 1972), holograms (Pribram, 1971), dynamic neural patterns (Sperry, 1969), or functional systems (Luria, 1973). Emotion was described by William James as the perception of patterns of autonomic consequences of action. More recent researchers, such as Schacter and Singer (1962), have added cognitive processes to autonomic arousal as an integral part of this pattern (Schwartz, 1975, p. 323).

With reference to the primary questions asked by the present investigation, it would appear, according to Schwartz (1975), that patterns of physiological processes and the cognitive/emotional activity that generates them (and is generated by them) are the central elements in the low arousal learning process.

In general, the physiological patterning effected by the subjects' cognitive/emotional strategies would appear to be reinforced by, as well

as reinforcing of, such strategies as a function of success during training. Specifically, this cognitive/emotional reinforcement appears to arise from two sources: (1) the "emergence" of cognitive/emotional activity consonant with patterned, low arousal activity, and (2) desirable changes in the feedback stimulus as a function of appropriate physiological alterations within the operant training situation.

Thus, where the cognitive/emotional strategies employed result in patterns of physiological activity consistent with desired training goals (e.g., toward low arousal), such strategies (as well as the patterned activity itself) will be reinforced in the above two ways and will gradually be acquired within the training context. Conversely, where the strategies employed result in patterns of physiological activity counterposed to desired training goals (e.g., toward high arousal or no change in arousal), such strategies (as well as the inappropriate physiological patterning occurring as a result) will be "aversively" reinforced and thus not acquired.

In view of the results of the present study, where the cognitive styles of the subjects are similar, one would expect successful vs. unsuccessful trainees to display (1) reliably more physiological patterning consonant with low arousal, and (2) reported cognitive/emotional strategies reliably more similar to spatial-intuitive thinking. However, where subjects' cognitive styles are counterposed, as in the present study, group differences in training performance should be greater than where cognitive styles are similar only to the extent that one of the two cognitive styles employed is generated by, and reinforcing of, low arousal, patterned physiological activity.

Although multi-system physiological recording was not employed in the present study, group differences in favor of spatial-intuitive subjects within single-system training were nevertheless found. Therefore, these available data suggest that (1) patterned physiological activity consonant with low arousal is more likely to be reinforced by, and reinforcing of, a set resembling spatial-intuitive vs. verbal-analytic thinking, and (2) spatial-intuitive subjects are more likely to generate alterations in patterned physiological activity (within an operant training situation) resulting in desirable changes in the feedback stimulus than verbal-analytic subjects.

These conclusions, however, require additional empirical support. Such support could be obtained via replication of the present study where (1) multi-system recording is employed during single-system training, or (2) multi-system recording is employed during multi-system training. In this way, group differences in patterned physiological activity could be examined in the light of cognitive style differences, differences in performance during training, and differences in reported cognitive/emotional strategies employed.

In summary, taking the results of the present study and Schwartz's (1975) formulation together, subjects engaged in successful low arousal biofeedback training are probably employing strategies related or similar to the cognitive/emotional activity generated by alteration toward low arousal of patterned physiological processes. Since spatial-intuitive subjects trained consistently better than verbal-analytic subjects (despite the fact that single-system training was employed), the present study offers some empirical evidence that the cognitive style brought to the training situation by successful subjects (e.g., spatial-intuitive thinking) was

reinforcing of patterned, low arousal physiological activity. Conversely, for the same reason, patterns of physiological processes associated with low arousal were reinforcing of spatial-intuitive cognitive/emotional activity within the training situation.

The latter point refers specifically to the acquisition of a spatial-intuitive cognitive/emotional set employed within the low arousal, operant training context. This should be distinguished from the acquisition of a generalized, spatial-intuitive cognitive style used on a daily basis and regularly identifiable via psychological measurement. Finally, although these concepts are related in a descriptive sense, the latter appears to be an internalized, more highly developed and generalized version of the former.

Consequently, it can reasonably be assumed that spatial-intuitive thinking more closely resembles the cognitive/emotional activity which emerges during self-regulated, multi-system, somatic movement toward low arousal than verbal-analytic thinking. While spatial-intuitive strategies were reinforced by (and reinforcing of) low arousal, patterned physiological activity, verbal-analytic strategies generally failed to effect low arousal, patterned activity at all. Therefore, such (verbal-analytic) strategies could not be extinguished via emergent cognitive/emotional activity (resembling spatial-intuitive thinking), which would ordinarily occur during the acquisition of low arousal, physiological patterns.

This view is supported by the results of the present study obtained in the absence of multi-system feedback which, if employed, should result in a considerably larger training difference between the counterposed cognitive style groups than that obtained here.

Finally, a note of caution is required with respect to the theoretical

discussion above. Specifically, in an effort to integrate the results of the present study with the rationale proposed by Schwartz (1975), (1) it was assumed that successful trainees (e.g., spatial-intuitive subjects) displayed low arousal, patterned physiological activity during training, while unsuccessful trainees (e.g., verbal-analytic subjects) did not. Although reasonable, this assumption should be verified via a similar study in which multi-system recording (during single- or multi-system training) is employed.

(2) It was also assumed that successful trainees (e.g., spatial-intuitive subjects) employed cognitive/emotional strategies resembling spatial-intuitive thinking during training and that unsuccessful trainees (e.g., verbal-analytic subjects) employed strategies resembling verbal-analytic thinking. Also reasonable, this assumption should be verified by obtaining unobstrusive measures of the strategies employed by the subjects throughout the training process (including baseline recording).

(3) In support of the view that spatial-intuitive thinking resembles the cognitive/emotional activity emerging from low arousal alterations of patterned physiological processes, it was proposed that spatial-intuitive subjects should perform even better within low arousal training than verbal-analytic subjects where multi-system _vs_. single system feedback is provided. Since this performance differential is central to the present discussion, it should be verified empirically before any further conclusions along this line are drawn.

Summary, Conclusion, and Practical Applications

We arrive now to the point at which the clinical/practical ramifications of the present study can be considered. Specifically, the following question will be addressed: What has been learned from this research and how can it

serve the needs of others?

Clearly, the most salient finding of this study concerns the interaction between thinking patterns and efficiency in voluntarily attaining states of low physiological arousal. That is, performance in low arousal biofeedback training is apparently predictable from psychological instruments which measure thinking patterns descriptively similar to the cognitive/emotional strategies reported to be effective during such training.

For example, we have found that persons perferring a generalized cognitive strategy based on non-specific, implicit, emotional cues and "gut feelings," and who respond to spatial cues almost as readily as verbal cues in a free-choice situation (e.g., spatial-intuitive persons) can attain voluntary control of low arousal states within a relatively difficult biofeedback training task (e.g., EEG frequency control) far better than persons preferring a strategy based on logical, explicit, non-emotional cues and a "rule following" approach, and who respond relatively little to spatial cues (e.g., verbal-analytic persons). However, we have also found that the difference between spatial-intuitive and verbal-analytic persons in voluntarily attaining low arousal states diminishes greatly where the biofeedback task requires relatively less "cognitive effort," such as with EMG frontalis control.

More important, we have learned that the two cerebral hemispheres interact in a complex way to facilitate the acquisition of low arousal responses via EEG biofeedback training. Specifically, success in dominant EEG frequency reduction (and probably other low arousal biofeedback techniques) appears to engage primarily the right hemisphere and/or inhibit the intrusive activity of the left hemisphere.

In addition, the "preferred" right hemisphere of spatial-intuitive

persons appears to be the appropriate choice for electrode placement where a rapid decrease in dominant frequency from resting levels is desired. On the other hand, a more pervasive and stable reduction of frequency appears to be facilitated by placement of electrodes over the "non-preferred" left hemisphere of these persons, so that "mental chatter" and related interference from this hemisphere can be more directly inhibited.

Further, although it is difficult for them to learn, we have found that low arousal states via low frequency activity may be effected by verbal-analytic persons with electrodes placed over their "preferred" left hemisphere for the same reason, and also because its activity is apparently more easily manipulated by them than that of their "non-preferred" right hemisphere. Finally, however, we have learned that cognitive style generally outweighs electrode placement where the voluntary attainment of low arousal states is concerned.

In attempting to explain these findings within a theoretical framework, it has been suggested that spatial-intuitive persons may already possess, to a certain extent, a learned predisposition toward the cognitive/emotional activity thought to be generated during multi-system, somatic movement toward low arousal. Verbal-analytic persons, on the other hand, apparently possess a disposition counterposed to such cognitive/emotional activity and tend to override the emergence of such activity by failing to "let go" of verbal-analytic strategies; thus, relatively higher arousal levels are maintained: Any success in training by these persons, therefore, apparently involves the relinquishing of verbal-analytic strategies along with the adoption of a spatial-intuitive cognitive/emotional set, the precursor for, and capacity for maintenance of which, spatial-intuitive subjects apparently bring with them to the training situation.

Finally, we have learned that success within a difficult biofeedback training task (e.g., dominant EEG frequency reduction) might increase one's coping ability as measured by Barron's Ego Strength Scale.

One major application of the findings of the present study lies in the clinical treatment of stress-related disorders. In view of the apparent sympathetic dysfunction which characterizes the autonomic nervous activity of person's suffering from stress-related disorders, the rehearsal and eventual acquisition of low arousal physiological response can aid in effecting both recuperative parasympathetic activity and the "re-education" of sympathetic control systems.

In this connection, any predictor of success within low arousal EEG training (or any other difficult biofeedback task) within a clinical setting would appear useful. For example, a large proportion of the negative findings reported in such training may be caused by a neglect of both the preferred cognitive mode of the client and, in the case of EEG training, placement of electrodes. Consideration of these variables could, in some cases, make the difference between rapid, successful training (and symptom amelioration, perhaps) and a lengthy, expensive, and frustrating experience with a psychological or biomedical helping facility, in general, and biofeedback training, in particular.

Probably the widest application of these findings concerns the additional evidence offered for existing behavioral differences among persons varying in cognitive orientation. The selective neurophysiological activity accompanying such differences (in this case, the acquisition of difficult physiological control), may have strong implications for learning ability in other situations.

Within education, for example, cirricula and other programs could be

selected and designed on the basis of the preferred cognitive modes of the pupils. However, rather than emphasizing one mode over the other, a balanced activation of the hemispheres could be taught by initially emphasizing the non-preferred mode, followed by a gradual shift to methods which activate both preferred and non-preferred modes.

In particular, students who find verbal-analytic task activity difficult or tiresome could be maintaining an inappropriate cognitive mode (i.e., relative right hemisphere activation) during such activity. In this case, they might be trained via EEG feedback techniques to either decrease right hemisphere frequency or increase left hemisphere frequency (or both) during this type of processing, thus sustaining the desired verbal-analytic mode. Conversely, persons who find it difficult to assimilate visually-presented material could be trained to produce the opposite interhemispheric asymmetry, thus sustaining the spatial-intuitive mode.

Moreover, students or persons who experience difficulty changing cognitive modes when necessary could be trained via EEG asymmetry feedback to shift cerebral asymmetry patterns at will. The interhemispheric, "spatial illusion," variable-pitch feedback technique developed by Ornstein and Galin (1973) and discussed earlier would be ideal for this purpose. These individuals could eventually shift voluntarily into the cognitive mode specifically appropriate for the task they are engaged in at the time.

Extending this application, EEG asymmetry feedback techniques could also be used to deal effectively with the cultural conflict in cognitive style suggested by Cohen (1969) and Marsh, Tenhouten and Bogen (1970). Specifically, the difficulties of urban poor children in school systems oriented toward the middle class may be explained by the latter's tendency to use the verbal-analytic mode and the former's tendency to use the

spatial-intuitive mode (Ornstein & Galin, 1973).

Thus, modification of teaching approaches emphasizing both cognitive modes (such as done by the Sesame Street television show, for example), along with appropriate cerebral asymmetry feedback training, could reduce specific learning disabilities and facilitate the reinforcement of productive learning skills.

Training for specific patterns of lateral asymmetry may also provide marked improvement for those suffering from dyslexia and stuttering. Orton (1934) has long held that these symptoms are caused by a lack of cerebral asymmetry. In this connection, Ornstein (1973) reports that lefthandedness, no hand preference, and mixed hand/eye preference (indicating reversed or mixed cerebral dominance) occur more frequently in clinical populations of stutterers, dyslexics, and those with specific learning disabilities than in normal populations. Thus, increased voluntary control of appropriate patterns of lateral asymmetry may help alleviate such symptoms.

Moreover, EEG feedback training programs for the treatment of attentional, emotional, and hyperkinetic problems, already in existence, could be re-structured on an individualized basis toward existing preferences for particular cognitive modes. Further, as discussed earlier, EEG asymmetry feedback techniques should prove useful for treating individuals with non-organic brain deficiency within either or both hemispheres. Such an individual could be trained to produce asymmetry patterns which reduce the major inhibitory component of a particular hemisphere's activity.

Still further, similar feedback techniques could be used to improve an individual's ability at a particular skill known to be mediated by one of the two hemispheres. A piano tuner, for example, might wish to "brush up"

on his tonal memory skills. In this instance, he might receive cerbral asymmetry feedback training shaped specifically toward right hemisphere activity during the task with minimal left hemisphere interference.

A final potential application of the results of the present study concerns the alteration of generalized cognitive strategies vs. the enhancement or inhibition of task-specific cognitive modes. Although the present study found that shifts toward intuitive thinking were unrelated to success in training, further research in this area is needed. Future studies generating methodology capable of altering generalized thinking patterns will have important implications for clinical psychology, psychiatry, and social rehabilitation.

In closing, an interesting theoretical notion concerning man's lateral specialization of cognitive modes has been offered by Galin (1974). Specifically, he notes a parallel between the mental processes of the right hemisphere and some aspects of Freudian primary process thinking and repression. Since intrahemispheric connections are stronger than interhemispheric connections (Bogen & Bogen, 1969), and on the basis of numerous experiments with commissurotomized individuals, Galin proposes that in normal intact people mental events in the right hemisphere (e.g., visual, tactile, kinesthetic, and auditory images) can become functionally disconnected from the left hemisphere (via inhibition of neuronal transmission across the cerebral commissures), and continue a "life of their own." Thus, his hypothesis suggests a neurophysiological mechanism for some instances of repression and an anatomical locus for unconscious mental events.

> Imagine the effect on a child when his mother presents one message verbally, but quite another with her facial expression and body language; "I am doing it because I love you, dear," says the words,

> but "I hate you and will destroy you" says the face. Each hemisphere is exposed to the same sensory input, but because of their relative specializations, they each emphasize only one of the messages. The left will attend to the verbal cues because it cannot extract information from the facial gestalt efficiently; the right will attend to the nonverbal cues because it cannot easily understand the words. In this situation, the two hemispheres might decide on opposite courses of action; the left to approach, and the right to flee. Because of the high stakes involved, each hemisphere might be able to maintain its consciousness and resist the inhibitory influences of the other side. The left hemisphere seems to win control of the output channels most of the time, but if the left is not able to "turn off" the right completely, it may settle for disconnecting the transfer of the conflicting information from the other side...It seems likely that each hemisphere treats the weak contralateral input in the same way in which people in general treat the odd discrepant observation that does not fit with the mass of their beliefs; first we ignore it, and then, if it is insistent, we actively avoid it.
>
> The mental process in the right hemisphere, cut off in this way from the left hemisphere consciousness that is directing overt behavior, may nevertheless continue a life of its own. The memory of the situation, the emotional concomitants, and the frustrated plan of action all may persist, affecting subsequent perception and forming the basis for expectations and evaluations of future input (Galin, 1974, p. 576).

Thus, the preference by individuals for one cognitive mode over another may reflect differential conscious accessability of repressed and/or unconscious psychological material, which may, in view of the present study and related work, be modifiable via EEG feedback techniques.

Epilogue

The present investigation was initiated in the hope of shedding light on the relationship between man's thinking patterns and his overt behavior through controlled scientific study. In closing, the author realizes how far some of the formulations in the present study are from the strict, operational boundaries that science wishes to maintain. However, it is felt that the value of scientific inquiry should not be limited to a perspective and method identical to that of the positivists, for example. In this light, the present study has attempted to maintain a balance

between respectable scientific methodology, on the one hand, and relevant inquiry, interpretation, and application on the other. Although some readers may be concerned primarily with conceptual problems and equivocal generalization of results, others will hopefully benefit from the clinical and social implications yet to be explored and developed out of this and related lines of work. Most important, however, the author hopes that this work has contributed to the further development of theoretical frameworks and related lines of research within which man's consciousness plays a central and important role.

APPENDIX A

BIOFEEDBACK TRAINING

Section 1 Background and Empirical Research

The core of Western science has traditionally assumed that voluntary bodily processes are consciously controlled through the cerebral cortex and craniospinal nervous system and that involuntary processes are automatically and unconsciously controlled by subcortical mechanisms and the autonomic nervous system. Further, it has been maintained that voluntary control of the autonomic nervous system cannot be demonstrated to any significant degree. Research has demonstrated, however, that (1) reliable voluntary control of the autonomic nervous system is indeed possible, and (2) biofeedback techniques can facilitate voluntary changes in normally involuntary physiological functions.

In evidence of these statements, recent empirical investigations with unusual or "adept" individuals have demonstrated unequivocally that remarkable voluntary control over normally involuntary functions is possible. Jack Schwarz, for example, an immigrant from Holland sometimes called a "Western Sufi," has reliably demonstrated his ability to stop and/or prevent entirely the bleeding of wounds on command, as well as demonstrating "pain control" by emitting no significant physiological pain responses (e.g., changes in heart rate, GSR, brain waves, muscle tension, etc.) while burning cigarettes were held against his forearm for 25 seconds or while an unsterilized knitting needle penetrated the skin, muscle,and a vein of his bicep (Green, Green & Walters, 1972; Green & Green, 1973; Pelletier &

Peper, 1975).

Moreover, Swami Rama, an Indian Yogi, has shown reliable voluntary control of his heart (effecting a 300 beat per minute atrial fibrillation on command), of his brain waves (emitting beta, alpha, theta, or delta frequencies at will, the latter normally occurring only during deep sleep), and of his blood vessels via skin temperature (effecting a 9 degree F. difference within 12 minutes between two spots located two inches apart on his palm) (Green, Ferguson, Green & Walters, 1970; Green & Green, 1975; Pelletier & Peper, 1975).

Further, Ramon Torres, an Ecuadorian meditator, has similarly demonstrated reliable control of bleeding and pain, as well as accelerated healing of body tissue (Pelletier & Peper, 1975).

Finally, it should be noted that every effort was made in these experiments (except healing) to determine whether striate muscular involvement (normally voluntary) was a plausible explanation for such remarkable control over "involuntary" processes. In no case was such involvement shown to be evidential. On the contrary, muscle activity and other electrophysiological measures taken during each demonstration indicated bodily movement toward a low arousal, hypometabolic state (see Green _et al_., 1972; Green & Green, 1973a; 1975; Pelletier & Peper, 1975).

In the last five to eight years a large body of evidence has accrued indicating that biofeedback techniques can facilitate one's capacity for voluntary control over "involuntary" physiological processes. For example, subjects receiving auditory and/or visual feedback when their brain waves of electroencephalographic (EEG) rhythms meet specific frequency and amplitude criteria have been able to gain voluntary control over such feedback stimuli (Kamiya, 1968; Brown, 1970; 1971; Beatty, 1971, Pamplin &

Bridges, 1973; Strayer, Scott & Bakan, 1973; Green, Green & Walters, 1974; Fehmi, 1974; Schwartz, Davidson & Pugash, 1975; Hord, Tracey, Lubin & Johnson, 1975; Kuhlman & Klieger, 1975; Moore, Dunster & Lang, 1975; Valle & Levine, 1975; Degood, Chisholm & Valle, 1975; Hardt, 1975; Woodruff, 1975).

Similarly, subjects receiving feedback regarding their muscle activity or electromyographic (EMG) amplitude levels at specific bodily locations, including the medial gastrocnemius (Amato, Hermsmeyer & Kleinman, 1973), masticatory area (Gessel & Alderman, 1971), buccinator (Basmajian & Newton, 1974), sternohyoid (Lyndes, 1975), extensor (Stoyva & Budzynski, 1974), massetor (Budzynski & Stoyva, 1973), upper trapezius (Otis, McCormick and Lukas, 1974), and frontalis (Stoyva & Budzynski, 1975; Connoly, Besserman & Kirschvink, 1974; Alexander, French & Goodman, 1975; Sime, Degood & Noble, 1975; Reinking & Kohl, 1975; Love, 1975; Kinsman, O'Banion, Robinson & Staudenmayer, 1975; Haynes, Moseley & McGowan, 1975; Degood, Chisholm & Valle, 1975; Alexander, 1975) have also been able to gain voluntary control over such feedback stimuli. A final example of the specificity and sophistication apparent in biofeedback training of EMG activity can be seen in studies where subjects have demonstrated voluntary control over single motor unit (SMU) activity (Harrison & Mortenson, 1962; Basmajian, 1963; 1970; 1973; Basmajian & Newton, 1974; Basmajian, Baeza & Fabrigan, 1965; Gray, 1971; Lloyd & Leibrecht, 1971; Fetz & Finnocchio, 1972; Kato & Tanji, 1972a; 1972b; Leibrecht, Lloyd & Pounder, 1973; Smith, Basmajian and Vanderstoep, 1974).

Additional examples of individuals gaining voluntary control over "involuntary" physiological processes (via appropriate feedback stimuli) include reliable training of alterations in heart rate (Engel & Chism, 1967; Schwartz, Vogler & Young, 1974; Williams, 1974a; Bell & Schwartz,

1975; Beazel, Appel & Murphy, 1975; Neyer, 1975; Levenson, 1975; Gatchel, 1975; Bouchard, 1975), skin temperature (Keefe, 1975; Turin, 1975; French, Leeb & Fahrion, 1975; Surwit & Shapiro, 1975; Fotopoulos, Cook & Lessen, 1975; Keefe & Gardner, 1975), blood pressure (Shapiro, Tursky & Schwartz, 1970; Steptoe & Johnston, 1975; Kleinman, Goldman & Snow, 1975; Goldman, Kleinman, Snow, Biders & Korol, 1975; Fey & Lindholm, 1975; Whitehead, Lurie & Blackwell, 1975), forearm bloodflow (Williams, 1974b), ventricular rate (Bleeker & Engel, 1973), galvanic skin response (GSR) (Greene, 1966; Johnson & Schwartz, 1967; Hughes & Shean, 1970; Abdullah, 1973), skin conductance (Lacroix & Roberts, 1975), respiration (Levenson, Manuck, Strupp, Blackwood & Snell, 1974; Teip, 1975), gastrointestional responses (Hubel, 1975; Engel, Nikoomanesh & Schuster, 1975; Furman, 1975; Welgan, 1975) and penile tumescence (Laws & Rubin, 1969; Henson & Rubin, 1971; Rosen, 1974).

It should be emphasized that "voluntary control" in these experiments (and hereafter within the present study) refers to the subject effecting reliable physiological changes from resting, pre-training baseline levels. For example, reliable changes in EEG frequency or amplitude (i.e., either changes in per cent time emission of specific EEG rhythms as defined by conventional frequency bands, or changes in integrated amplitude within one or more conventional frequency bands) or reliable changes in EMG amplitude, as compared to pre-training baseline levels, would be evidence for "voluntary control" of the respective physiological modality under consideration.

Further, despite the fact that much of the EMG work has been done with muscles that can be affected voluntarily by normal persons, the salient variable distinquishing the facilitative effect of an informational, bio-electric feedback loop from the EMG control achievable without it appears

to be the degree of voluntary control achieved. For example, the frontalis or forehead muscle can be relaxed voluntarily only to a certain degree (e.g., baseline level). However, as the literature indicates, it can be voluntarily relaxed to a reliably greater degree than yoked controls, for example, with EMG biofeedback training. Another example can be seen in persons requiring various types of muscle rehabilitation. Basmajian, Kukulka, Narayan and Takebe (1975) reported that in hemiparietic patients with chronic foot drop, EMG biofeedback training increased their strength and range of motion two times more than a group receiving a standard physical rehabilitative technique, with the biofeedback group retaining conscious control of dorsiflexion in an occupational setting.

Thus, although "voluntary control" via biofeedback training may refer to the willful alteration of strictly autonomic processes without the training device, it usually refers to the demonstration of reliable self-regulated alterations in any monitored physiological process, strictly autonomic or centrally-mediated, in which performance beyond the asymptotic baseline level would normally be considered outside the range of self-regulation.

Section 2 Theoretical Discussion

The issue of whether biofeedback training can be conceptualized as operant conditioning is currently in warm debate. Apparently, the sway of the pendulum toward operant conditioning (vs. perceptual differentiation, mediation, or habituation) depends on which physiological functions are discussed.

For example, there appears to be little current resistance to the idea that responses mediated by the autonomic nervous system, once thought conditionable only through classical techniques, can be modified by operant

conditioning methods and are changed by these procedures in a manner highly similar to somatically-mediated responses (Miller, 1969; Miller, DiCara, Solomon, Weiss & Dworkin, 1969; Kimmel, 1974). In experiments following the basic design outlined in Miller et al. (1969), reliable increases and decreases in the following autonomically-mediated functions have been shown: heart rate (Trowill, 1967; Miller & DiCara, 1967; Miller & Banuazizi, 1968; DiCara & Miller, 1968a; 1968d; 1969), blood pressure (DiCara & Miller, 1968e), peripheral (DiCara & Miller, 1968b; 1968c) and internal (Miller & DiCara, 1968) vasomotor responses, rates of formation of urine by the kidney (Miller & DiCara, 1968), rate of secretion of saliva (Miller & Carmona, 1967), and contractions of the intestines (Miller & Banuazizi, 1968; Banuazizi, 1968).

An example of the type of study providing evidence for such a view would be one which uses modification procedures commonly used with other operants, such as schedules of reinforcement. Shapiro and Crider (1967) used schedules of reinforcement (variable ratio) to operantly condition human skin potential responses, while fixed ratio schedules (Greene, 1966) and an avoidance schedule (Sutor & Greene, 1968) were used in the operant conditioning of skin resistance responses.

Examples such as these are common throughout the literature involving autonomically-medicated responses, but stumbling blocks to straightforward interpretation are nevertheless present. One common argument is that instrumental autonomic conditioning in humans can never be unequivocally demonstrated because of our inability to control adequately for skeletal or cognitive mediation (voluntary, centrally-mediated responses) (Katkin & Murray, 1968). Although skeletal behavior may always be a possible mediator of changes in autonomic behavior, Kimmel (1974) summarizes evidence that "possibility" and "actuality" are not identical in this regard.

For instance, operant GSR conditioning was demonstrated in subjects who were reinforced for GSR responses occurring only in the absence of EMG activity (Rice, 1966). Moreover, Van Twyver and Kimmel (1966) reported reliable differences between conditioned and yoked control groups even when all GSR's occurring close in time to respiration irregularities or EMG activity were eliminated from their data. In addition, subjects who were reinforced for making deep respirations, which elicited GSR's, learned the skeletal respiratory response while the GSR's habituated (Gavalas, 1968). The latter finding, an "uncoupling" of skeletal and autonomic responses, was especially relevant since if the observable skeletal responses (i.e., respiration) did not produce pseudo-operant changes in the autonomic response (GSR), then it seems unlikely that unobseravable skeletal responses would.

The issue of cognitive mediation is obviously more complicated, since it is related to the issue of whether human learning can occur without awareness of the contingencies. Kimmel (1974) reports that 200 subjects from his conditioning experiments were adamantly unaware of reinforcement contingencies, based on intensive interviews. However, other researchers have reported that subjects' cognitive-skeletal strategies were central in conditioning attempts, whether successful or not (e.g., Brener, Kleinman & Goesling, 1969; Stern, 1967).

The problem seems to lie in exactly how "cognitive mediation" is defined and the conditions under which it is or is not invoked as an explanation for autonomic conditioning. If a person uses cognitive activity non-specific to the immediate task (such as imagining himself lying on a bed or floating on a raft to elicit reinforcement for heart rate slowing), as opposed to cognitive activity specific to the task

(simply thinking of his heart slowing down), then it may perhaps be invoked as an explanation for such an autonomic change. In other words, according to Kimmel (1974), cognitive mediation should best be reserved for those instances of apparent operant conditioning of autonomic functions where the subject reports thinking of a specific situation or event which could conceivably elicit the autonomic response, and in which the subject also reports consistent occurrences or even increases in the occurrence of such a cognition. Kimmel (1974) elaborates succintly on this point:

> When nothing more is meant by cognitive mediation than what is necessary to perform an unusual or rare skeletal response, such as wiggling the ears, nothing is gained by its invocation (unless, of course, the cognition involved in ear wiggling is imagining that one is a bird or a rabbit). Making a GSR, a vasoconstriction or dilation, slowing or speeding the heart, or increasing or reducing blood pressure or salivation, all may be assumed to be at least as difficult as moving one's ear, and cognizing in the form of scanning for some kind of proprioception is surely to be expected (p. 45).

Clearly, there is no easy solution to the cognitive mediation issue. Moreover, the enormous amount of data presently available in this area will inevitably be interpreted differently by different people. However, most of the more recent studies have included controls for, or methods designed to investigate the extent of, skeletal, cognitive or other mediators. A relevant example is a study of Lang and Melamed (1969), in which a nine month old infant was conditioned to eliminate ruminative vomiting via electric shock punishment, which was triggered by reverse peristalsis from the esophagus by an EMG transducer. Even more central to the mediation issue is a study by Schwartz (1971), whose subjects demonstrated that they could learn to simultaneous raise their blood pressure while lowering their heart rate.

In summary, the data discounting both skeletal and cognitive mediation

appears supportive enough to state with reasonable confidence that such mediation is sufficient but not necessary to effect operant modification of autonomic functions.

On the other hand, researchers do not agree that biofeedback training of centrally-mediated processes (specifically EEG activity) can be viewed as bona fide operant conditioning. Lynch and Paskewitz (1971), for example, consider that in a strict sense the operant control of EEG alpha (8-13 Hz) activity is operationally indefensible since any alpha control is necessarily mediated by a number of physical/somatic and attention/arousal variables. More specifically, visual effects of ambient light during training were found to result in reliable increases in alpha densities compared to resting baselines, whereas in total darkness no such increases were found, even by the same subjects (Paskewitz & Orne, 1973). These results prompted the authors to conclude that, since the effects of ambient light reduces the amount of baseline alpha present (see Mulholland, 1969), any reliable increases beyond these suppressed baselines are simply alterations in basal alpha levels, rather than operant increases beyond baseline levels taken under "optimal conditions." In addition, cognitive factors caused specifically by the feedback situation (e.g., attention, boredom, feelings of evaluation, trial by trial progress, and the degree of stimulus habituation via the mode of feedback) can strongly affect the subjects' motivational and emotional state during baseline recording and training.

In view of these physical and cognitive factors, Lynch and Paskewitz (1971) conclude that investigators cannot claim that operant conditioning of alpha densities has occurred when bidirectional changes are the sole measure of such claims (e.g., reliable differences in alpha densities between "alpha on" and "alpha off" trials). More specifically,

unidirectional alpha suppression is apparently easily learned, but unidirectional alpha increases beyond baseline levels taken under "optimal conditions" cannot be shown since (1) baseline levels taken before the experiment are contaminated by novelty effects, apprehension of learning trials, visual effects (if taken under dim ambient light), and lack of habituation and adaptation, and (2) baseline levels taken during training are contaminated by changes in the emotional or motivational state of the subject during the course of the experiment. With respect to this latter point, Kamiya (1969) found baseline alpha levels taken between learning trials to increase over each session, attributing these increases to the subjects' decision to maintain their preferred mode of consciousness during the waiting period.

In summary, Lynch and Paskewitz (1971) and Paskewitz and Orne (1973) believe that alpha activity occurs in the feedback situation only when an individual ceases to pay attention to any of a number of cognitive, somatic, or emotional stimuli which normally block alpha. Trial-to-trial increases resembling learning curves are said to be the result of inhibition of alpha blockers (or disinhibition of alpha itself). Finally, Strayer, Scott and Bakan (1973) feel that contingent feedback does not necessarily function as reinforcement for operant control of EEG activity, but rather may serve only as a cue for perceptual differentiation, which aids in the identification of internal events.

Specifically investigating these parameters of alpha enhancement, Travis, Kondo and Knott (1974) used random stimulus and no feedback groups in eyes closed alpha training (i.e., no ambient light) and found that increases in emitted occipital alpha were related to contingent operant reinforcement of feedback stimuli. Moreover, yoked controls have been employed by Beatty (1971) and Hord _et al_. (1975), who also found alpha to

be modifiable by operant methods. Finally, Hardt (1975) raises major objections to studies which fail to show reliable operant alpha conditioning. These largely include inadequate methodology and the lack of consideration of individual differences.

With regard to methodology, Hardt (1975) considers the different kinds of feedback stimuli employed, the variability in scoring methods of EEG activity, and most of all, the total training time allotted, to be the major shortcomings of studies failing to show reliable operant alpha conditioning. More specifically, Lynch and Paskewitz (1971) trained their subjects for a total of 20 minutes following only 11 minutes of acclimation time. It is not suprising that habituation and adaptation were salient factors in view of this short baseline period, and 20 minutes of training would seem hardly sufficient to gain reliable operant control of a stimulus reflecting subtle physiological activity. In contrast, Hord _et al_. (1975) recorded a total of 63 minutes of baseline alpha activity and trained their subjects for a total of 630 minutes.

In view of these discrepancies, Hardt (1975) believes that the first two hours (120 minutes) of alpha training might simply be adaptation and habituation. In analyzing the data from a number of alpha feedback studies, he found that applying the best fitting polynomial least squares curve resulted in alpha learning curves most closely resembling a 5th order function. More importantly, however, he found that such a best fitting curve predicted (by extrapolation) rapid increases in alpha densities beyond 320 minutes of training. In view of these and other studies, he states that during the first three hours, physical, cognitive, and emotional factors dominate in the EEG biofeedback situation, but that after this time (and only after this time) alpha densities can be increased reliably.

Finally, in discussing the role of individual differences in biofeedback training, he reviews evidence that indicates that high ego strength individuals (see Barron, 1956) are characterized by a high degree of physiological responsivity, an ability to change, and that his own, as well as Ancoli's (1975) and Valle, Chisholm, and Degood's (1975) alpha enhancement results can be predicted by use of the Ego Strength (Es) scale. These studies are reviewed in more detail in Appendix B.

In summary, without balancing all of the operant conditioning literature (autonomic and central) on the shoulders of psychology's current crisis over the definition of conditioning (see Lynch & Paskewitz, 1971), it can be stated with reasonable confidence that centrally-mediated responses are also subject to modification by operant methods. However, except in the area of EMG training (see Blanchard & Young, 1974), unequivocal evidence for the operant conditionability of central processes (e.g., non-mediated alpha), although existent, is rare, and certainly cannot be considered representative of the current popular and professional views of non-mediated EEG conditionability.

Section 3 Functional Rationale: Greens' INS and OUTS Theory

Considering the livliness of the debate over the status of biofeedback training as an operant method, it is surprising to note that few functional theories delineating the specific mechanisms and processes involved in the technique have been offered. Except for frequent reference made to the cognitive strategy known as passive volition, an apparent requisite for the attainment of low arousal states via biofeedback training (see following section), and occasional reference to the concept of feedforward, an additional term borrowed from systems control theory (see Pribram, 1975; Turner, 1975), few attempts have been made to outline the specific nature

in which biofeedback training "works."

One such attempt, however, has been offered by Green and Green (1975). The theory is based entirely on their postulated psychophysiological principle. which states that

> Every change in the physiological state is accompanied by an appropriate change in the mental-emotional state, conscious or unconscious, and conversely, every change in the mental-emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state (Green, Green & Walters, 1970, p. 12).

More specifically, this statement affirms that it may be possible to bring under some degree of voluntary control any physiological process that can be continuously monitored, amplified, and displayed, and that from a theoretical perspective, coupling this principle with volition makes psychophysiological self-regulation possible. The following description will attempt to illustrate how this is possible (see Figure 1).

Figure 1 is meant to be a highly simplified representation of processes that occur in the voluntary/involuntary neurological system and simultaneously, in the conscious/unconscious psychological system. The upper half of the diagram represents the normally conscious, voluntary domain (localized in cerebral cortex and craniospinal apparatus) and the lower half represents the normally unconscious, involuntary domain (localized in the subcortical brain and autonomic nervous system).

The boxes in the diagram are labeled according to their role in internal vs. external stimulation and conscious vs. unconscious processes. For example, the boxes on the midline of the diagram (divided by horizontal centerline) represent the fact that both conscious and unconscious physiological structures, in the form of emotional or mental responses, emit electrical activity in response to perceptions of normally conscious,

outside-the-skin events (OUTS) (see Arrow 1). The "limbic response" box is naturally placed entirely in the unconscious section of the diagram (see Arrow 2), although some neural pathways lead directly to cortical regions from limbic structures, implying that "information" of some kind from limbic structures has the potential of reaching consciousness. Parenthetically, studies in both animals and humans have associated the limbic system with emotional states via its correlated electrical activity (see Papez, 1937; MacLean, 1949).

Central to the Greens' rationale is that the limbic system is connected by neural circuitry to the "central control panel" of the brain, the hypothalamus, which in turn controls the "king gland" of the body, the pituitary (see Arrow 3). That the perception of OUTS can effect a sequence of activity in the limbic system, hypothalamus, and pituitary, which in turn can produce physiological responses or states (see Arrow 4) resulting in an overt behavior change, can be seen in the example of an individual fainting upon witnessing some horrible event or where a sudden increase in heart rate or blood pressure is experienced in response to some external stimulus situation.

Further, if a normally unconscious physiological response is detected by an electrical transducer (e.g., electrode) of some kind and displayed to the individual (see Arrow 5) through a normally conscious sensory modality via biofeedback, then a "new" emotional or mental response (see Arrow 6) will be made to normally unconscious, inside-the-skin events (INS). The "new" emotional/mental response will cause a "new" limbic response (see Arrow 7), which the Greens postulate will combine with, replace, or modify the original limbic response (Arrow 2). This "new" limbic response, a conglomerate of partially conscious and partially unconscious emotional/ mental responses to both OUTS and INS (the latter via biofeedback), will

thus develop a modified pattern of hypothalamic firing and pituitary secretion, consequently resulting in a modified physiological response or state.

Therefore, it is postulated, a biocybernetic control loop is set up as a result of providing the "conscious cortex" with information about normally unconscious INS events. The Greens' logical conclusion is that closing the biocybernetic loop bridges the normal gap between conscious and unconscious processes (i.e., voluntary and involuntary processes), and thus, the dynamic equilibrium (homeostasis) of the system can be brought under voluntary control.

It should be emphasized that during voluntary control of normally involuntary (unconscious) processes, individuals do not become aware of the neural pathways and muscle fibers involved any more than they become aware of what cerebral and subcortical processes are involved in hitting a tennis ball. However, as in the case of the tennis ball (or any learned skill), if external objective feedback is received (via verbal instruction of vidiotape) then the internal "set up" can be modified in such a way that external changes in the desired direction are achieved.

In discussing the eventual stage where the biofeedback instrument is no longer required for voluntary control, the Greens address themselves to Arrows 5, 6, 8, 9, and 10 of the diagram. They stress that biofeedback information, along Arrows 5 and 6, is eventually unnecessary as a person's sensitivity to INS events develops (see Arrow 8). In other words, as the individual's sensitivity to INS events develops, he can theoretically, bypass the amplification of his INS events and maintain dynamic equilibrium of any physiological system. He accomplishes this through effecting his own emotional/mental responses, limbic responses and hypothalamic/pituitary

responses as a result of his increased sensitivity (e.g., Arrow 8, then Arrows 10, 7, 3, 4, and 9). Finally, the Greens cite this exact sequence (i.e., the "closing of the internal cybernetic loop") as a likely pattern of activity underlying the remarkable physiological control evident among classical yoga practitioners and the unusual, "adept" individuals described earlier.

Section 4 The Role of Volition

Directly related to the "INS and OUTS" theory, which Green and Green (1975) purport as the biomechanics of biofeedback, is the idea of volition, since some mechanism or force would seemingly be required to close the biocybernetic loop and enable it to be functional. It clearly becomes difficult to agree with strict behavioral accounts that self-regulation is impossible, that human behavior is a product only of genetic patterning and environmental conditioning, and that freedom is an "illusion" (Immergluck, 1964; Lefcourt, 1973) when considering the data from recent biofeedback research, and especially, the remarkable data from recent studies of unusual or "adept" individuals, some of which was described earlier. Such data substantiates the belief that humans are not neurological or biochemical machines, without choice or self-control, and that they certainly can be responsible to some degree for their psychophysiological behavior. The concept of self-regulation implies that at some level within us there is an "essence of being," with or without a discernable physiological substrate, that can choose a specific response or a generalized behavior (i.e., make a choice) and maintain the conditions under which that response or behavior will be performed (i.e., make it happen), as well. In other words, it appears that the concept of freedom must be affirmed in

order to initiate a self-regulatory process (Green & Green, 1973b), Space does not permit further discussion of this issue, which remains philosophical in the absence of empirical evidence for the physiological substrate underlying volition.[19]

As mentioned earlier, a subject undergoing low arousal biofeedback training does not learn to reduce, for example, his EEG frequency or EMG amplitude per se, rather he gains proficiency in eliciting a particular psychological state or set which is accompanied by or correlated with relatively lower EEG frequency or EMG tension levels.

Biofeedback training thus appears to be a highly specific task. In one way, it can be viewed as essentially a cognitive shaping procedure involving successive approximation. Individuals undergoing successful biofeedback training experience a gradually increasing awareness of cognitive/emotional strategies that alter the target physiological process in the desired and undersired direction (e.g., decreases and increases in muscle tension). Desired feedback from the electronic monitoring device validates or positively reinforces effective cognitive strategies, while undesired feedback invalidates or aversively reinforces ineffective ones. Consequently, desired levels of physiological activity are maintained through the gradual acquisition of effective cognitive/emotional strategies.

Interestingly, when considering the range of psychological states that could potentially be effective, it becomes apparent from biofeedback and related literature that the cognitive/emotional strategy required to gain low arousal control over a wide range of psychophysiological processes (e.g., EEG, EMG, skin temperature, heart rate, blood pressure, etc.) is singular and unique. The most common label applied to this strategy among biofeedback researchers is passive volition (Green & Green, 1973b), whereas

autogenic therapists or researchers refer to it as passive concentration (Schultz & Luthe, 1969), meditators often refer to it simply as concentration (Null, 1974) or relaxed wakefulness (Naranjo & Ornstein, 1971), and within one common relaxation technique it is referred to as open focus (Fehmi, 1975).

In contrast to active volition, which involves a deliberate, objective effort toward a goal, passive volition requires that the individual assume a calm, subjective, effortless set toward the task at hand. This relaxed, "letting go" strategy appears to be the critical variable involved in successful low arousal biofeedback training and is, in fact, held to be a prerequisite to self-generated changes in normally involuntary physiological processes.

> Returning to the matter of active and passive volition, the normally involuntary, unconscious sections of one's self can be induced to behave in ways that are consciously chosen by visualizing what is wanted, asking the being (body, mind, brain, unconscious, or whatever) to do it, and then *detaching* oneself from the results. A symbolic way of putting it is to say that the cortex plants the impulse in the subcortex and then allows nature to take its course, without *interference*. This is passive volition.
>
> The operational situation suggested by "the cortex plants" is remarkably analogous to farming. There seems to be a correspondence between human physiological responses to volition and the way "nature" responds in general to human initiative. For instance, the farmer (a) desires and visualizes the crop, (b) plants the seed, (c) allows nature to take its course, and (d) reaps. . .The patient must allow his psychophysiological machinery to function naturally, without anxiety or *analytically* "picking at" what he is trying existentially to do. The farmer does not dig up his seeds to see if they are sprouting (emphasis added) (Green & Green, 1973b, p. 6).

Again, this passive psychological set appears most appropriate for an individual attempting unidirectional control of any physiological modality toward low arousal, or a more hypometabolic state, which is the most common application of biofeedback training. In bidirectional biofeedback training, the individual gains proficiency in alternating between passive and active

volitional states, the latter being required to maintain higher arousal levels such as with increased EEG frequency or EMG amplitude (Green & Green, 1973b).

Additional descriptive terms used in reference to this effective cognitive/emotional set include non-attached, non-focused, non-reactive, non-limiting, non-logical, non-interfering, non-linear, non-specific, non-affirming, non-denying, effortless, implicit, global, and spatially diffused (Fehmi, 1975). Conversely, linear, logical, rule-following, active, goal-seeking, specific, effortful, focused, or sequential cognition based on explicit cues has been used to describe the cognitive/emotional strategy apparently ineffective within low arousal biofeedback training (e.g., active volition) (Fehmi, 1975), but which is apparently effective within high arousal training (Green & Green, 1973b).

The central relevance of passive and active volition, and the specific appropriateness of the biofeedback task as an empirical tool with which to investigate the role of two counterposed cognitive styles within low arousal training, is delineated in Appendix B.

APPENDIX B

COGNITIVE STYLE

Section 1 Introduction and Behavioral Research

One of the most interesting facets of the human experience is our ability to think. Covert behavior enriches our personal and social existence immeasurably, as can be seen in the complexity of our own awareness of self and others acting in harmony with the needs of our biological structure. Even more interesting, perhaps, is the observation that individuals use different cognitive strategies in dealing with their environments, again as a reflection of the "similar but different" quality which pervades our entire physical and psychological existence.

However, people use relatively few dimensions of cognitive organization to handle various life situations. These stable features of organization are called cognitive controls or "styles." According to Denmark, Havlena and Murgatroyd (1971),

> Most (such) conceptualizations are bipolar; usually one pole involves greater responsiveness to the environment or external influences on the stimulus, whereas the opposite pole indicates the degree to which such influences may be ignored (p. 133).

Thus, the term "cognitive style" has been used to refer to individual consistencies in generalized cognitive behavior from the individual's perceptual and conceptual organization of the external environment (Kagan, Moss & Sigel, 1963).

A number of different dimensions have been suggested within the rather general domain of cognitive style. There is one characteristic, however, which is common to a number of these dimensions. Although various labels

are applied to this characteristic, it is concerned primarily with the manner in which an individual perceives and analyzes a complex stimulus configuration. The two poles of this dimension are characterized by subjects who analyze and differentiate the components of the stimulus complex and by subjects who fail to analyze and differentiate the components and respond to the "stimulus as a whole" (Davis & Klausmeier, 1970). Kagan _et al_. (1963) classified the former subjects as analytic and the latter as relational, and believed that their classification system was similar to the field independent-dependent classification of Witkin, Lewis, Hertzman, Machover, Meissner and Wapner (1954). A similar classification system was suggested by Gardner (1953) in which the continuum was described as ranging from differentiated to undifferentiated subjects: there appeared to be one dimension which involved an active analysis on the one hand and a more passive, global acceptance of the entire stimulus on the other.

Thus, despite Plato's "triune" character of the soul and Hippocrates' postulated "four humours,"(see Gilbert, 1972) the general trend in categorizing thinking processes has largely been a duality: creative _vs_. constrained, parallel _vs_. sequential, global _vs_. logical, etc. Gittin's (1969) comparison of analytically-oriented chemists and arithmetically-oriented artists is a good example of the individual difference approach that compares the behavior of people characterized by the dominance of different modes of cognition.

In addition, Bieri (1955) has employed tests of cognitive complexity to distinguish the cognitive styles of students in different major areas. Further examples include comparisons of perceptual and conceptual schemes on the Galileo chute judgment task (Lindahl, 1968), comparisons of logical

vs. empirical solution of the Sander parallelogram (Benjafield, 1969) and studies of reflective *vs*. impulsive thinking (Kagan, Rosman, Day, Albert & Phillips, 1964). Skinner (1969) postulates a cognitive duality, as well: he sees a rule-following or analytic strategy and an intuitive, contingent mode. Finally, science itself has traditionally rested on two complementary modes of thought. Specifically, Polanyi (1966) argues that scientific problem solving requires an ability to vacillate between intuitive and analytic modes.

Relevant to the present investigation, data from a number of additional studies concerned with thinking and behavior suggest that a person's cognitive style influences his performance on a variety of learning tasks. Fitzgibbons, Goldberger and Engle (1965), for instance, found that recall and recognition of social words incidentally presented was reliably correlated with cognitive style (field dependence). Similar findings in tactile-form discrimination were reported by Vaught and Ellinger (1966). Successful performance in problem solving was found by Guetzkow (1951) to be correlated with high performance on the Embedded Figures Test, a measure of cognitive style. Gardner and Long (1961) have demonstrated that many of their subjects' cognitive styles were related to serial learning. Davis and Klausmeier (1970) found that individuals identified as analytic on the Hidden Figures Test experienced little difficulty in identifying concepts, while low analytic subjects experienced considerable difficulty. Moreover, Rappoport (1965) reported that intuitive pairs of subjects learned a Multiple Probability Learning (MPL) task more rapidly and at a higher degree of final accuracy than analytic subjects.

Finally, demonstrating how task demands and structure can potentially elicit alternative cognitive modes, Gilbert and Rappoport (1972) have

induced shifts from purely analytic strategies to more image-laden, intuitive thinking. More specifically, intuitive subjects performed effectively on an imagery task, but were found deficient on a simple dot estimation task. The analytic subjects in the study were highly successful on the dot estimation task, but demonstrated a total absence of embedded imagery perception. However, both intuitive and analytic subjects avoided serious error on either task in the presence of stroboscopic interference, indicating that task demands can alter elicited cognitive modes. It was noted in the study, however, that analytic subjects appeared to hold tenaciously to the mode of analysis during the tasks, with some reported as "(having) employed simple formulae" (p. 7).

Related to the present investigation (i.e., within a biofeedback training context), this may be seen as analogous to reports of subjects failing to modify the feedback stimulus reliably in various low arousal settings when employing analytic strategies. Conversely, subjects who relinquished linear cognitive strategies, concentrating more on the global, phenomenal aspects of the learning task, were reliably more successful at low arousal biofeedback training (see Green & Green, 1973).

Section 2 Electrophysiological Research

In addition to the experiments cited in Appendix B, Section 1, research involving differential cognitive modes and electrophysiological measures has yielded useful data toward better understanding the relationship between thinking and behavior. The inclusion of electrophysiological recordings within conventional cognitive research provides a valuable source of increased reliability and validity in support of behavioral statements made about individuals categorized under one cognitive style or another. Moreover, such measures can aid significantly in the necessary process of

combining the large number of overlapping cognitive dimensions invoked which may not differ as greatly as believed. In view of this concern, one personality construct having received considerable electrophysiological attention is separately reviewed.

Ego strength. Noting that the interpersonal coping abilities most relevant to psychological integration include the ability to accurately assess and respond to the behavior of others while simultaneously "maintaining the integrity of the constellation of previously learned self-percepts called the ego," and that "the ability to maintain ego integrity is ego strength" (p. 317), Roessler (1973) attempted to define the physiological correlates of coping ability, and more specifically, of ego strength.

The Es (ego strength) scale (Barron, 1956) from the Minnesota Multiphasic Personality Inventory (MMPI) has proved to be useful in terms of identifying persons who differ physiologically. Test-retest correlations of .80 to .90 in various samples have been obtained despite the evidence of appreciable error of measurement (Roessler, 1973).

For example, Roessler, Alexander and Greenfield (1963) found that change in skin resistance, finger blood volume, and muscle potential in response to six intensities of a 1000 Hz tone was directly related to ego strength (i.e., the greater the change, the higher the ego strength) in a mixed group of psychiatric patients. Replicating the study with a "normal" sample (e.g., medical and dental students), Roessler, Burch and Childers (1966) found that even after four retests over a three month period, high Es subjects again responded with a greater change in skin resistance and all subjects maintained their ranks in responsivity. Roessler, Burch and Mefford (1967) found that high Es subjects excreted more catecholamines while anticipating comprehensive examinations than during a basal period

and those high Es subjects tested closest to the exams excreted more than those tested earlier. Low Es subjects, on the other hand, did not excrete more catecholamines prior to exams and those tested closest to the exams did not excrete any more than those tested earlier. The authors interpreted these results as evidence of greater physiological discrimination in the high Es subjects (i.e., they responded more appropriately: strongly to an anticipated threat, less to a small threat).

To further test this hypothesis, Roessler and Collins (1970) examined differences in heart rate, GSR, and basal skin conductance in response to more complex stimulation. They found that in response to a stressor film high Es subjects exhibited higher physiological levels than low Es subjects. They also found that high Es subjects showed a greater difference among their responses to the three discrete accidents portrayed in the film, and that they showed a greater difference between their overall response to the stressor film and their overall response to a pleasant film. Moreover, Strausbaugh and Roessler (1970) found higher skin conductance in high Es subjects on a vigilance task following sleep deprivation compared to a group of high Es subjects who had no sleep deprivation, and no differences between the low Es groups under the same conditions. This experiment also contained a feedback condition for errors on the vigilance task consisting of electric shock to the calf and a no feedback condition. Subsequently, following sleep deprivation the high Es subjects responded more under the feedback condition than under the no feedback condition, while the low Es subjects failed to show such a difference.

The authors interpret the results of these two studies as further evidence of an ability in high ego strength subjects to respond discriminatively physiologically, an ability which low ego strength subjects

apparently lack. Additionally, Roessler (1973) states that high ego strength subjects show more physiological responsivity, in general, through the relative lack of ego defenses they use in dealing with their environments:

> If a strong ego is one characterized by many and strong defenses frequently employed, then all stimuli including threatening ones would be so reduced in intensity in the process of perception that lesser physiological responses would occur; this is the opposite to the results reported here. On the other hand, if a strong ego is one characterized by little or no perceptual defense all stimuli would be perceived fully, but less threatening ones less intensely than more threatening ones. We would therefore expect such a person to respond more to threatening stimuli and less to non-threatening ones. This latter prediction is consonant with the experimental results which have been reviewed here (p. 325).

Roessler's (1973) results and their implications appear directly related to the general aim of the present investigation, which is to demonstrate that specific individual differences (e.g., cognitive) can predict performance within biofeedback training. Hardt (1975) states that high ego strength individuals, due to their high degree of physiological responsivity, should be more successful at biofeedback training than low ego strength individuals. Indicating that such persons are not "stuck" at either too high or too low a physiological level, he points out that high ego strength individuals have an ability to change in response to feedback, thus implying that Es scores should be a good predictor of biofeedback training.

In support of these statements, Hardt (1975) offers observational data providing evidence that Es scores are related to biofeedback training. Specifically, he found that the alpha training results of Ancoli (1975), Valle, Chisholm and DeGood (1975), and Hardt (1974) could be predicted on the basis of Es scores. For example, Ancoli (1975) found the introversion-extraversion dimension unrelated to alpha control and Hardt noted that introversion-extraversion correlated only .09 with Es (see Roessler, 1973).

Moreover, Ancoli (1975) also found that introspective, low authoritarian subjects were more successful with alpha feedback training than non-introspective, high authoritarian subjects. Reasoning that her dimension is thus very similar to the Repression-Sensitization (R-S) scale, Hardt noted that a reliable negative correlation between the R-S and Es scales (-.75) was found (see Roessler, 1973). Finally, Hardt noted that Valle, Chisholm and DeGood's (1975) alpha training data, as well as his own (1974), were negatively related to anxiety and that Roessler (1973) found a reliable negative correlation (-.76) between Es and anxiety (i.e., Taylor scale).

In conclusion, Hardt (1975) states that we should not fail to recognize the confluence of Eastern psychological insights and Western discoveries in psychophysiological and biofeedback research: whereas Eastern meditative emphasis on egolessness and non-attachment are prerequisites of growth toward "higher consciousness," minimal ego defenses (e.g., high Es scores) appear to be positively related to the ability to increase alpha levels toward those seen in advanced meditators (see Green et al., 1970; 1975; Pelletier & Peper, 1975).

EEG research. When examining electroencephalographic work in this area more specifically, it can be seen that since the human EEG was first introduced and described by Berger in 1929, there have been many attempts to correlate brain wave frequencies with various aspects of personality. Lemere (1936) first reported a relationship between "good" and "poor" alpha rhythms and cyclothymic and schizoid personalities, respectively. Gottlober (1938) found a correlation between a high alpha index (per cent time) and extraversion. However, citing numerous methodological flaws in Gottlober's and similar studies, Broadhurst and Glass (1969) found that introverts (Eysenk, 1959) emitted both greater per cent time and amplitude of alpha

than extraverts, which contradicted predictions made by Eysenk based on his theory of Pavlovian cortical inhibition and extraversion. In addition, these authors found that subjects with low neuroticism scores also showed greater per cent time alpha than those with higher neuroticism scores, which is more congruent with Eysenk's posited relationship between neuroticism and autonomic responsivity (see Fenton & Scotton, 1967). Further, Mundy-Castle (1956) found EEG frequency to be correlated with "secondary functioning," which is tantamount to more differentiated or analytic thinking (see Wiersma, 1932; Biesheuvel, 1949).

The not uncommon opinion that EEG and intellectual functioning are unrelated is based largely on the assumption that "since both alpha and beta (14-30 Hz) activity appear to be quite primitive functions of neural tissue," the EEG should not be expected to relate to "complex and phylogenetically recent" mental functions (Ellingson, 1966). This assumption has been challenged by Vogel and Broverman (1966), who have maintained cogently that the relative scarcity of evidence linking the EEG to complex mental behaviors is due less to a failure to find relationships than it is to a failure to initiate relevant research.

In view of this situation, Vogel, Broverman and Klaiber (1968) reported an inverse relationship between beta activity and the Automatization Cognitive Style, defined as greater ability (strong automatization) or lesser ability (weak automatization) to perform simple repetitive tasks than might be expected from the individual's general level of intellectual performance on a battery of heterogenous tasks (Broverman, 1964). More specifically, automatization, or habituation to a class of stimuli, resulted in the disappearance of beta activity, as predicted, since there was no longer any need to re-orient to that class (Vogel <u>et al</u>., 1968).

Along the same line, Beckman and Stein (1961) found that more efficient problem solvers, as defined by subjects' capacity to derive and integrate a series of logical relationships, showed less alpha in their resting EEG than inefficient problem solvers. The authors' interpretation of these data was that efficient problem solvers operate at a higher level of "cortical arousal," due to their constant alpha blocking, and are thus in a constant state of readiness to integrate external information or retrieve information stored in the cortex. It should be noted that these results contradict those of Vogel et al. (1968), where decreases of beta activity during strong automatization suggests that lower frequencies, specifically alpha and theta (4-7 Hz), are closely associated with mental efficiency.

More importantly, however, it should be noted that Beckman and Stein's data are based on resting EEG levels, whereas Vogel's et al. data are based on EEG measures taken during active intellectual effort. Parenthetically, Galin and Ornstein (1972) have stressed that the latter technique is more likely than the former to reveal meaningful relationships between EEG and cognition.

Two studies focusing on the more differentiated or analytic mode provide additional evidence for a relationship between EEG and cognitive style. First, Becker-Carus (1971) found that "rigidity" in thinking was associated with high alpha frequencies (12-13 Hz) and poor performance on a vigilance task (rapid responses to light). Good vigilance, as in Vogel's et al. (1968) study, correlated positively with low alpha (8-9 Hz) measured during the tasks. Second, in a study where subjects were categorized into four levels of cognitive activity according to Harvey's measure of belief system, Tucker, Ray and Stern (1974) found that those showing greater differentiation (i.e., more analytic) were found to have a greater magnitude of lateral EEG

asymmetry in the temporal (T) and parietal (P) lobes, greater disparity of asymmetry across T, P, and occipital (O) lobes, and a greater variation in EEG patterns over tasks than less differentiated (i.e., more intuitive) subjects.

Taken together, these two studies suggest that the analytic mode or more differentiated cognition involves a higher and less synchronous level of generalized EEG frequencies, as well as a greater and more complex asymmetrical EEG distribution between the two cerebral hemispheres. These rather general findings are further developed in light of current electrophysiological evidence indicating a strong relationship between the two cerebral hemispheres of the brain and cognitive functioning.

Section 3 Hemispheric Specialization and Lateral Asymmetry

Through the work of Galin and Ornstein (1972; 1974), Durnford and Kimura (1971), Gazzaniga (1967), Milner (1971), and McKee, Humphrey and McAdam (1973), it has been demonstrated that the left hemisphere of the brain is primarily involved with analytic thinking, especially language and logic. This hemisphere seems to process information sequentially, which is necessary for logical thought since logic depends on sequence and order. The right hemisphere, by contrast, appears to be primarily responsible for our spatial orientation, artistic talents, body awareness, recognition of faces, and intuitive-holistic or "gut feeling" cognition. It processes information more diffusely than the left hemisphere and integrates material in a simultaneous, rather than linear fashion (Ornstein, 1973).

Stressing that the "focal" orientation of the left hemisphere operates independently of the "diffuse" orientation of the right hemisphere, Sperry

(1964) suggested that the two hemispheres may differ in their physiological organization, as well. In view of Sperry's observations, Galin and Ornstein (1972) investigated the EEG's of normal people while they were processing verbally and spatially and found that if a person engages in a verbal-analytic task, the alpha rhythm in his right hemisphere increases. Similarly, if he works on a spatial-holistic problem, the alpha rhythm in his left hemisphere increases. Ornstein (1973) further asserts that increased alpha production is a sign of decreased information processing and that the normal brain seems to "turn off" the hemisphere not engaged in a task (and "turn on" alpha), as if to reduce interference from that hemisphere. Of course, the "turning off" of either hemisphere during a specific task necessarily refers to the relative dominance of one EEG frequency range or amplitude level over another between the hemispheres (e.g., lateral asymmetry), since the hemispheres function simultaneously (Patterson, 1975).

In a study investigating individual differences in cognitive style, Galin and Ornstein (1974) found that subjects whose vocations emphasized verbal-analytic modes (e.g., lawyers) used fewer upward and more rightward reflective eye movements than subjects whose vocations emphasized spatial-holistic modes (e.g., ceramicists). While citing numerous supporting studies (e.g., Kocel, Galin, Ornstein & Merrin, 1972; Kinsbourne, 1972), the authors noted that rightward eye movements increased left hemisphere activity, while leftward eye movements increased right hemisphere activity. As evidence to this point would suggest, they concluded that preference for verbal-analytic activity results in more rightward reflective eye movements and left hemisphere activation (i.e., higher dominant EEG frequencies and lower amplitude), while preference for spatial-holistic activity results in more leftward reflective eye movements and right hemisphere activation.

Evidence for lateral EEG asymmetry by task has been demonstrated in a study by Dumas and Morgan (1974), in which the proportion of occipital alpha amplitude in the right hemisphere relative to the total amount of alpha decreased during visuo-spatial tasks and increased during linguistic and mathematical tasks. In general, a suppression of alpha activity relative to the total amount of alpha was found in the hemisphere that was "active" or processing information. This finding was also reported by Morgan, MacDonald and Hilgard (1974) in an earlier study, along with the additional finding that occipital alpha amplitude was higher in the right hemisphere for baseline (resting) laterality as well as during both verbal and spatial tasks. During the tasks, alpha amplitude dropped reliably below the baseline (resting) amplitude in both hemispheres, but these decreases were not reliably different within each hemisphere by task.

Again, it was the relative amount of alpha between the hemispheres during different activities that defined the laterality effect. Morgan et al. noted that task difficulty, or relative "cognitive work," could be responsible for the lateralized alpha effect, but Dumas and Morgan controlled for this and found no effects due to task difficulty alone.

In a sophisticated and well-controlled study, Doyle, Ornstein and Galin (1974) used discrete Fourier transform analysis and homologous leads (e.g., T_4/T_3, P_4/P_3) to compute ratios of power (amplitude) between the hemispheres in conventional frequency bands. These amplitude ratios (right/left) were found to be reliably higher in verbal-arithmetic tasks than in spatial-holistic tasks primarily in the alpha band, with the beta and theta bands showing this effect less consistently. The delta (1-3 Hz) band showed no systematic effect of laterality by task. The authors noted that whenever a task dependence of asymmetry appeared in any frequency

band, it was in the same direction: the hemisphere primarily engaged in the cognitive activity developed proportionately less power relative to the total amount present in both hemispheres. Finally, and most important, differential power ratios were not caused only by an increase or decrease of power in bilateral leads over the same cerebral lobe; often a shift in power was caused by an increase in a parietal lead in one hemisphere along with a decrease in a temporal lead in the opposite hemisphere (e.g., P_{4+}/P_{3o} & T_{4o}/T_{3-}) or vice versa (Doyle *et al.*, 1974).

Galin and Ornstein's (1972) earlier study, which found ratios (right/left) of average power (1-35 Hz) to be greater in verbal than spatial tasks, noted that individuals probably alternate between cognitive modes rather than integrating them. In other words, although these modes complement each other and it is possible to process complex spatial relationships in words, they noted that it seems much more efficient to use visual-kinesthetic images.

> Consider what most people do when asked to describe a spiral staircase; they begin using words, but quickly fall back on gesturing with a finger (p. 413).

In retrospect, the line of work pursued by the authors in this section clearly reveals more specific and meaningful electrophysiological correlates of differential cognitive activity than that in the previous section. More specifically, experiments which examine generalized EEG activity recorded from a single location while the subject is resting (e.g., Beckman & Stein, 1961) must be considered inferior to those in which independent recordings are taken from a number of homologous leads, considered to be functionally and anatomically appropriate, while the subject is engaged in a highly specific and controlled task requiring a singular type of cognitive activity (e.g., Doyle *et al.*, 1974). Thus, current statements regarding EEG

parameters and cognitive styles must make reference to the cerebral hemisphere recorded from (e.g., dominant vs. non-dominant), the location of electrode placements, and the frequency band(s) within which amplitude shifts are noted.

Summarizing in light of these considerations, it can generally be seen that analytic activity (recorded from T, P, and O) engaged the left (or dominant) hemisphere in slightly higher dominant frequencies along with considerably reduced amplitude within the alpha band, while simultaneously engaging the right (or non-dominant) hemisphere in slightly lower dominant frequencies along with considerably increased amplitude within the alpha band. However, since the right (non-dominant) hemisphere emits more alpha in the resting state than the left[20] (see Raney, 1939; Kiloh & Osselton, 1966), spatial-intuitive activity produces the same basic hemispheric engagement but on a relative basis.

More specifically, during spatial-intuitive activity, dominant frequency in the left hemisphere is slightly reduced along with a considerable increase in amplitude within the alpha band while, simultaneously, the right hemisphere shows slightly higher dominant frequency (but still lower than the left), along with a relatively slight reduction in amplitude within the alpha band. In other words, during verbal-analytic activity the hemispheres appear lopsided in terms of amplitude levels within alpha (i.e., right greater than left), but during intuitive-holistic activity the hemispheres approach equivalent levels of amplitude within alpha (i.e., right slightly greater). Finally, it should be noted that these laterality relationships break down somewhat when the left hemisphere is not the dominant one, such as in lefthanded persons (or righthanded persons with a familial background of lefthandedness) (see Galin & Orstein,

1972; 1974).

In view of these more specific findings, a central question now becomes whether task lateral asymmetry varies in a particular way among individuals preferring specific generalized cognitive modes. Experimentation attempting to demonstrate differential lateral asymmetry in persons with different cognitive orientations was conducted by Dumas and Morgan (1974). They found that although artists displayed reliably higher overall alpha amplitude than engineers, there were no reliable differences between them in hemispheric laterality by task. Specifically, most of the artists in the study reported visualization strategies on difficult math items and the engineers reported that they had poor visual memories and chose verbal coding as the preferred strategy on facial memory tasks. However, the EEG measures indicated that the artists used their left hemisphere for all of the math items and the engineers used their right hemisphere for the facial memory tasks, despite their verbal reports.

However, noting that Dumas and Morgan's (1974) study was subject to methodological problems, including the lack of functionally and anatomically appropriate electrode placement (e.g., only occipital leads were used), Patterson (1975) investigated the lateral asymmetry and baseline (resting) EEG's of intuitive, analytic, and quasi-rational undergraduates (see Baumgardner, 1973) using bilateral temporal and parietal electrode placement. Although the results were not evaluated for statistical reliability, it was found that intuitive subjects generally showed higher EEG baseline amplitude at lower dominant frequencies than analytic subjects.

This finding concurs with one reported by Morgan <u>et al</u>. (1974), in which subjects high in hypnotizability were found to have higher amplitude than low hypnotizable subjects during baseline recording. Moreover, these

authors also found that mean laterality scores during hypnosis were almost identical to those obtained during spatial (i.e., right hemisphere) tasks. Relatedly, Bakan (1971) has suggested that hypnosis might be a right hemisphere task because of the low arousal characteristics of the relaxed hypnotic state or possibly because of the significant role that imaginative involvement plays in hypnosis.

More important, Patterson (1975) found that intuitive subjects displayed task laterality through increases and decreases in right hemisphere amplitude, while analytic subjects showed laterality through changes in left hemisphere amplitude at higher dominant frequency. Support for this finding is provided by Ornstein and Galin (1973), who found that lawyers displayed laterality via greater changes in left hemisphere amplitude than ceramicists. Moreover, the ceramicists displayed laterality via greater changes in right hemisphere amplitude than the lawyers. However, the ceramicists' greater right hemisphere sensitivity was not statistically reliable.

Indirect support for Patterson's (1975) findings can be found in Doyle et al.'s (1974) investigation where, as mentioned earlier, in normal subjects not matched for preferred cognitive mode, variability in the hemisphere leads producing task-specific laterality was reported. In other words, amplitude shifts in the same leads from the same cerebral lobe or hemisphere did not consistently produce the laterality effect; individual differences existed in terms of which lead on which hemisphere produced laterality during any particular task sequence. Follow-up data which might have revealed subject differences in existing generalized preferences for specific cognitive modes were unfortunately not gathered. Consequently, correlations could not be computed between such data and the various hemisphere leads responsible for laterality by task.

Further indirect support for Patterson's results[21] can be found in the study mentioned earlier by Tucker et al. (1974), who reported differential task lateralized asymmetry among subjects categorized as having greater or lesser differentiation in their conceptual structure. In view of their results, the authors concluded that "subject variables are important in understanding EEG asymmetry" and that "EEG research may have relevance to theories of cognitive development" (p. 236).

The larger implication of the findings of Patterson (1975) and Ornstein and Galin (1973) is central to the present investigation. Specifically, intuitive subjects (or subjects within a "right hemisphere" occupation) demonstrated a particular right hemisphere sensitivity, whereas analytic subjects (or subjects within a "left hemisphere" occupation) demonstrated a left hemisphere sensitivity, during the display of lateral asymmetry by task. In view of the wealth of evidence supporting lateral specialization of cognitive mode, it is not surprising that the "preferred" hemisphere (aligned with the preferred mode) in these subjects was found to be responsible for the task laterality phenomenon.

Moreover, this unique, highly specific sensitivity by hemisphere, if bona fide, may mediate additional behavioral differences among individuals counterposed in cognitive style, as well. This might be particularly true where the behavioral task under investigation (e.g., low arousal EEG biofeedback training) is linked directly to the electrophysiological activity within the hemispheres that defines such sensitivity differences (e.g., EEG frequency and amplitude).

APPENDIX C

PSYCHOLOGICAL INSTRUMENTS

Section 1a Construction of Baumgardner's Intuitive-Analytic Questionnaire

The intuitive-analytic distinction described in Chapter 1 was originally tested by Baumgardner using 47 statements developed from interview protocols. At that time, undergraduates (n=120) rated each item according to how much it reflected analytic or intuitive thinking on a 1 (highly analytic) to 5 (highly intuitive) scale, with 3 as the uncertain point. Given a brief description of what these terms meant, students had little difficulty rating most of the items.

Based on Thurstone-type scaling procedures (cf. Crano & Brewer, 1973), items were selected for their consensual validity using the means and standard deviations of these ratings. Only those items with relatively high means (at either the intuitive or analytic extreme) and low standard deviations were chosen. Specifically, items were selected as analytic when the sum of the item mean and item standard deviation did not extend into the intuitive range (i.e., did not exceed 3.0). Items were selected as intuitive when the difference between the item standard deviation and item mean did not extend into the analytic range (i.e., was not less than 3.0). This selection criterion insured that the majority of ratings of selected items was on one or the other side of the uncertain boundary (see Baumgardner, 1976).

The selection procedure yielded 15 analytic and 12 intuitive statements. Analytic items emphasized logical-rational thought based on objective

premises (e.g., "My college vocational aptitude scores showed this field to be a logical choice"), while intuitive items emphasized global and personal-subjective feelings as the criterion for choice of majors (e.g., "In the long run it is best to follow your gut feelings no matter what other people say"). Social desirability ratings by an independent sample of 30 students revealed no significant differences in the apparent desirability of intuitive and analytic statements (see Baumgardner, 1976).

Subjects in the present investigation were instructed to indicate the degree to which each questionnaire item was characteristic of their thinking toward choice of their present major on a 1 (very important) to 5 (very unimportant) scale, with 3 representing the neutral point. Via computer, a score was compiled for each subject, reflecting the relative importance of analytic and intuitive statements. The 1 to 5 scale was changed to a -2 to +2 scale for analytic items, and a +2 to -2 scale for intuitive items. Responses to each item were than added together, producing a single score for each subject.

Scores could potentially range from -54 to +54. Higher scores (i.e., the more intuitive items endorsed and/or analytic items not endorsed) were interpreted as indicative of intuitive thinking and lower scores as analytic thinking (see Baumgardner, 1976).

In summary, the Intuitive-Analytic Questionnaire contained 27 items which elicit preferred cognitive strategies used in considering the choice of a college major. The items were constructed such that subjects rated from 1 to 5 (i.e., in relative importance) each of the 27 statements in regard to choosing a college major. Computer-analyzed responses indicated preference for a non-specific, implicit,or "gut" feeling approach (intuitive maximum score = +54) or a logical, explicit,or "hypothesis testing" approach

(analytic: maximum score = -54). The intuitive approach is exemplified by the statement "I can personally identify with the people who work in this area." Thus, emotional involvement and global feelings, not proceeding from objectively specifiable premises, are taken as definitive for this mode of thought. In contrast, the statement "My college vocational aptitude scores showed this field to be a logical choice" exemplifies the analytic approach, where objectively determined premises lead to logico-rational conclusions (see Baumgardner, 1976).

Section 1b Baumgardner's Intuitive-Analytic Questionnaire

PLEASE READ CAREFULLY:

This experiment will investigate the relationship between the styles of thinking used by people in different situations and their ability to alter one of their bodily processes through biofeedback training. The first part of the study (i.e., this questionnaire) deals with finding out how people think about choosing academic majors. At a later date, after the questionnaires have been scored, some of you will be asked to meet with us and eventually undergo 5 weeks of biofeedback training. For this reason, we would like you to PRINT your name, address and phone number on the large information sheet and your name and social security number on the small (IBM card) answer sheet (blackening the appropriate spaces with the pencils provided).

IMPORTANT:

(1) Do not write or make any marks on the questionnaire. All responses will be made on the two answer sheets provided (inside the questionnaire).

(2) Please be sure that ALL blanks on the large information sheet are filled in completely. Similarly, be sure that your name and social security number are correctly placed on the small (IBM card) answer sheet.

(3) Please sign the statement of consent below and carefully read all instructions before marking your answers to the questions on the small (IBM card) answer sheet.

(4) Finally, please place both sheets back inside the questionnaire when you have finished.

STATEMENT OF CONSENT (please sign):

I understand that I am volunteering to answer this questionnaire, and should I decide not to fill it out, I will not be penalized in any way.

Signed______________________________

Date________________________________

THANK YOU VERY MUCH FOR YOUR COOPERATION!

Present major____________________________________

List the majors you have had from past to your present major.
1st.____
2nd.____
3rd.____
4th.____
5th.____

For all the questions that follow, use the IBM answer sheet. Use the numbers beside the response alternatives as a guide in filling out the answer sheet.

Make sure to: (1) fill in the blanks completely making no stray marks, (2) use a #2 pencil, and (3) check the correspondence between the number of the item on the questionnaire and the answer sheet before making each rating.

1. Sex
   male - 1
   female - 2

2. Year in school
   Freshman - 1
   Sophomore - 2
   Junior - 3
   Senior - 4
   5th year or Graduate - 5

3. Overall grade point average
   1.0 - 2.0 - 1
   2.1 - 2.5 - 2
   2.6 - 3.0 - 3
   3.1 - 3.5 - 4
   over 3.5 - 5

4. Major grade-point-average (if you haven't had enough classes to establish a major GPA, give overall GPA).
   1.0 - 2.0 - 1
   2.1 - 2.5 - 2
   2.6 - 3.0 - 3
   3.1 - 3.5 - 4
   over 3.5 - 5

5. How many majors have you had?
   1 - 1
   2 - 2
   3 - 3
   4 - 4
   5 or more - 5

6. Will you graduate in your present major?
   yes - 1
   no - 2
   uncertain - 3

7. How long have you had your present major?
   1 semester - 1
   2 semesters - 2
   3 semesters - 3
   4 semesters - 4
   5 semesters or more - 5

8. How likely is it that you will change majors?

1	2	3	4	5
very likely	moderately likely	uncertain	moderately unlikely	very unlikely

9. How satisfied are you with your present major?

1	2	3	4	5
very satisfied	moderately satisfied	uncertain	moderately unsatisfied	very unsatisfied

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Listed below are statements concerning why individuals choose a particular major. Using the scale below indicate the extent to which each statement was important in choosing <u>your present major</u>.

1	2	3	4	5
very important	moderately important	uncertain	moderately unimportant	very unimportant

For example: If your parents had a strong influence on your choice for a major, you might rate the item below, 1 - very important.

"I chose my present major because I'm following the advice of my parents."

I chose my present major because:

10. it seems like the best way to gain the financial success I want.

11. in the long run it is best to follow your gut-feelings no matter what other people say.

12. I did well in this particular subject in high school.

13. a warm feeling of personal admiration for a college instructor led to my interest in this field.

14. according to statistical surveys and opinions of professionals this area will become very important in the future.

15. in this area the difference between correct and incorrect work is always clear.

16. a college counselor showed me that this field was a logical choice.

17. the faculty and students you meet in this area are my kind of people.

18. my high school vocational aptitude test scores showed this field to be a logical choice.

19. the course requirements in this field allow great flexibility and freedom of choice.

20. it deals with ideas and abstractions which require mental discipline and careful logical thought.

21. I can identify personally with the people who work in this area.

22. of my high school experience with the complexities and ingenious methods and theories in this area.

23. it is emotionally satisfying to me now.

24. my college vocational aptitude scores showed this field to be a logical choice.

25. a high school counselor showed me that this field was a logical choice.

26. work in this area is always dynamic and changing.

27. of my college experiences with the complexities, and ingenious methods and theories in this area.

28. a warm feeling of personal admiration for a high school teacher led to my interest in this field.

29. in this area there is nothing ambiguous about the material.

30. it will prepare me for work from which I can gain great emotional satisfaction

31. It will allow me to fulfill an ambition I have had since I was a young child.

32. at a gut-level this is the area I think I should be in.

33. in my present major I deal with problems which have correct and verifiable solutions.

34. it will enable me to work in a large organization providing maximum security and fringe benefits.

35. statistical analysis and projections of the job market show that this is a rational way of preparing for a good job.

36. my personal feelings and experiences are relevant to the subject matter.

Section 2a Construction and Administration of Galin and Ornstein's Word-Shape Preference Test

Each of the 66 items on Galin and Ornstein's Word-Shape Preference Test consisted of three shapes with a word printed on each. Two of the shapes were similar or "fit together" (but were not indentical), as did two of the words (e.g., tobacco-church-smoke; city-town-smile). The odd word and odd shape never coincided. The subjects were instructed to choose an odd member of the trio and that either choice was correct; they would be scored only on speed. They were advised that some persons found the verbal and some found the spatial cues easier to use on different items and that they should pick whichever was "quickest and most natural" for them. Forced choices (i.e., only one oddity present) were inserted after every fourth item for the purpose of interrupting a response set.

In view of the large number of subjects performing this task (four sessions; 45-75 subjects per session), a bogus scoring method was employed by the author and two assistants. Specifically, the subjects were told that the time taken to complete the task would be their only score. In addition,

it was stressed that any errors committed would undesirably increase their score in the following manner: TEST SCORE = #SECONDS TO COMPLETION + 5(#ERRORS). Finally, in order to appear as though some amount of accuracy was involved in rank ordering the subjects' times, the following set-up was carefully administered during each session:

First, the subjects were reassigned to three independent sections of the lecture hall (i.e., approximately equal numbers of subjects per section). Second, an operative tape recorder interfaced with 3 microphones was placed in clear view of all subjects. Third, each subject was given a sheet describing the task procedure, on the back of which was printed a large number; the subjects were instructed to raise this number in plain view of the experimenters as soon as they completed the task. Fourth, the subjects were told that the tape recorder would be activated when the task began and that each experimenter would score a section of the hall by reading into his respective microphone the number held up by each subject as he finished, thus making a permanent record on the tape. Finally, it was explained that at a later date each subject's score would be determined by timing the interval between the initiation of the task and the appearance of his number on the tape. This method was felt adequate to monetarily divert the subjects' attention from the primary function of the task and also to minimize errors.

<u>Section 2b</u> <u>Galin and Ornstein's Word-Shape Preference Test</u>

IMPORTANT: Fill in <u>name, address, phone number, and subject number</u> (taken from the back of next sheet) on the last page of this booklet.

Please read carefully (along with experimenter):

DO NOT TURN BEYOND THIS PAGE UNTIL YOU ARE TOLD TO DO SO!!

On each page of this booklet there are sets of three items arranged in rows. Two of the three items are alike and fit together in some way. Your task is to select which item is different in each row and doesn't belong with the other two.

The six examples on the sample page will illustrate. (TEAR OFF THIS AND THE NEXT SHEET AND EXAMINE SAMPLE PAGE) As you can see, there are three designs or shapes in each row. Each design has a word printed on it. In the first row all the words are the same. Most people would say that the first and second shapes go together and the third one doesn't belong. Would you agree? OK, then mark a slash(/) through the third item.

In the second row most people would say that the first shape is different and the last two go together. Do you agree? OK, then mark a slash (/) through the first item.

In the third row the shapes are all the same, but the words HORSE and SADDLE go together and the word FAULT doesn't belong. Do you agree? OK, then mark the third item in that row with a slash (/).

Which item would you pick as the odd one in the fourth row? Mark a slash through it.

In the fifth row you could choose either a word that doesn't belong or a shape that doesn't belong. Which is the odd word? Which is the odd shape? EITHER ONE of these answers is right. Put a slash through either one of them.

The last row also has two possible correct answers. Which is the odd word? Which is the odd shape? Put a slash through either one of them.

On some of these sets of items people find it easier or more natural to pick out the odd word, and on some they find it easier to pick out the odd shape. EITHER WAY IS CORRECT. We want you to make your selections whichever way seems most comfortable and natural to you.

Since every set of items can be answered correctly, mark CAREFULLY only ONE slash in each row. An <u>ERROR</u> will be made if more than one slash appears in each row. An <u>ERROR</u> will also be made if you slash through an item which is <u>neither</u> the odd shape <u>nor</u> contains the odd word. GO AS FAST AS YOU CAN WITHOUT MAKING ANY ERRORS. Your score will be <u>how long (# seconds) it takes you to get to the end, plus five times the number of errors made</u>. More specifically,

SCORE = #seconds to completion + 5(#errors).

Obviously, working fast is important, but only if errors are very few!!!

To facilitate accurate scorekeeping, we have sectioned off the room and placed you as you are. Each of us is holding a microphone through which we can record the time it takes each of you to finish. More specifically, we would like you to say "<u>STOP</u>" and hold up this sheet, with your <u>SUBJECT</u>

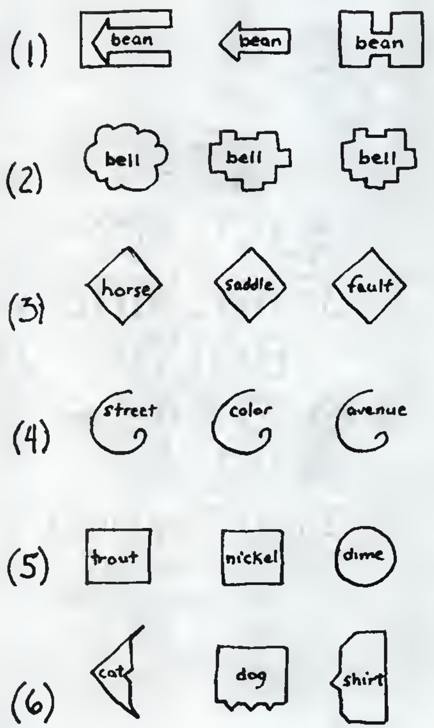
NUMBER FACING US, at the very instant you are finished. One of us will then point to you and read your number into the microphone, thereby making a permanent record on the tape of when you finished. Finally, as soon as you see and/or hear your number being read into the microphone, you will lower your number out of sight, OK?

Once again: As soon as you're finished say "STOP," hold up your subject number, wait until it is read into the tape recorder, and then lower it out of sight immediately.

Are there any questions? Remember, go as fast as you can making as few errors as possible. When I say "BEGIN," turn to the next page and get started.

BEGIN

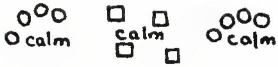
SAMPLE ITEMS



DO NOT TURN PAGE

UNTIL INSTRUCTED TO DO SO

TEST ITEMS

(1) 

(2) 

(3) 

(4) 

(5) 

(6) 

(7) 

(8) 

(9) 

(10) 

(11) 

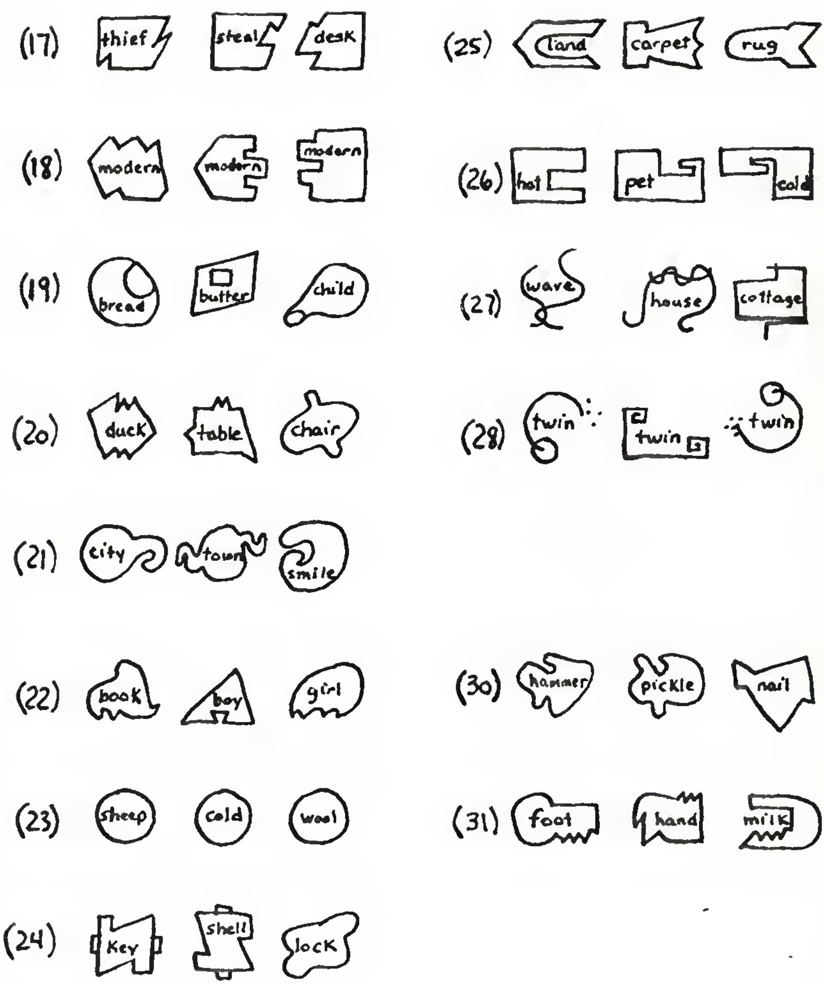
(12) 

(13) 

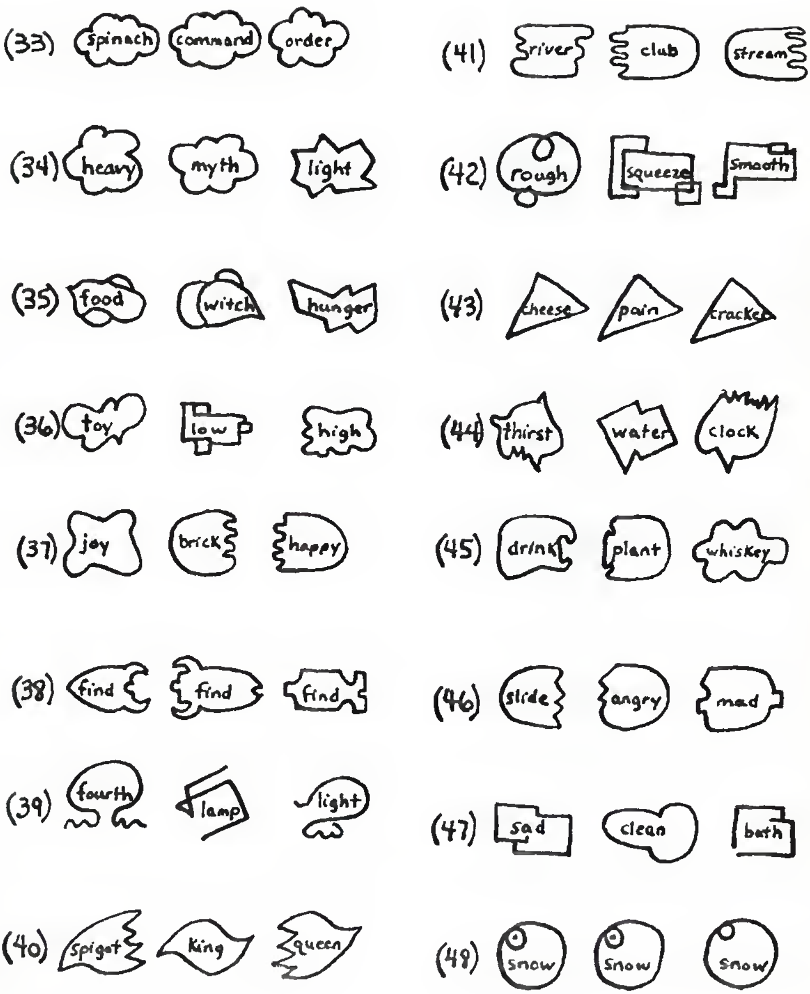
(14) 

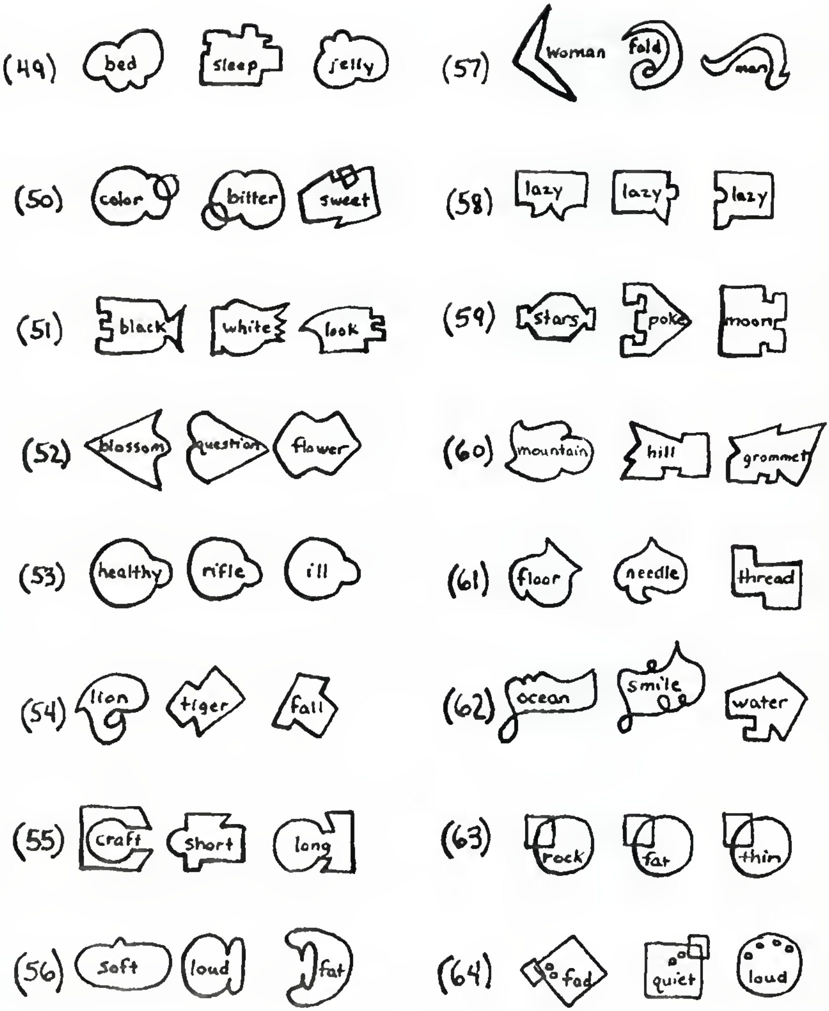
(16) 

KEEP GOING


(17) thief steal desk
(18) modern modern modern
(19) bread butter child
(20) duck table chair
(21) city town smile
(22) book boy girl
(23) sheep cold wool
(24) Key shell lock
(25) land carpet rug
(26) hot pet cold
(27) wave house cottage
(28) twin twin twin
(30) hammer pickle nail
(31) foot hand milk

KEEP GOING


(33) spinach command order
(41) river club stream
(34) heavy myth light
(42) rough squeeze smooth
(35) food witch hunger
(43) cheese pain cracker
(36) toy low high
(44) thirst water clock
(37) joy brick happy
(45) drink plant whiskey
(38) find find find
(46) slide angry mad
(39) fourth lamp light
(47) sad clean bath
(40) spigot king queen
(48) snow snow snow


(49) bed sleep jelly
(50) color bitter sweet
(51) black white look
(52) blossom question flower
(53) healthy rifle ill
(54) lion tiger fall
(55) craft short long
(56) soft loud fat
(57) woman fold man
(58) lazy lazy lazy
(59) stars poke moon
(60) mountain hill grommet
(61) floor needle thread
(62) ocean smile water
(63) rock fat thin
(64) fad quiet loud

KEEP GOING

(65) deep shallow flower

(66) doctor street nurse

(67) print dream sleep

(68) duty duty duty

(69) eagle bird march

(70) eating lake food

(71) foot shoe cake

(72) fruit silence apple

SAY **STOP**, AND HOLD UP YOUR SUBJECT NUMBER

Section 3 Barron's Ego Strength Scale

This inventory consists of numbered statements. Read each statement and decide whether it is true as applied to you or false as applied to you.

You are to mark your answers on the answer sheet you have. Look at the example of the answer sheet shown at the right. If a statement is TRUE or MOSTLY TRUE, as applied to you, blacken between the lines in the column headed T. (See A at the right.) If a statement is FALSE or NOT USUALLY TRUE, as applied to you, blacken between the lines in the column headed F. (See B at the right.) If a statement does not apply to you or if it is something that you don't know about, make no mark on the answer sheet.

	T	F
A.	■			
B.				■

Remember to give YOUR OWN opinion of yourself. Do not leave any blank spaces if you can avoid it.

In marking your answers on the answer sheet, be sure that the number of the statement agrees with the number on the answer sheet. Make your marks heavy and black. Erase completely any answer you wish to change. Do not make any marks on this booklet. Remember, try to make some answer to every statement.

BEFORE BEGINNING, PLEASE FILL OUT THE FOLLOWING:

Name (please print) ____________________

Address ____________________

Telephone Number ____________________ Subject Number # ____________________

YES NO (circle) If the computer selects me for the final phase of the experiment, I will be available for 20 sessions of biofeedback training (Monday through Thursday, at my selected hour each day or evening) starting March 8 but excluding Spring Break (March 15-19).

*****DO NOT MAKE ANY MARKS ON THE QUESTIONNAIRE*****

BEGIN:

1. I have a good appetite.
2. I have diarrhea once a month or more.
3. At times I have fits of laughing and crying that I cannot control.
4. I find it hard to keep my mind on a task or job.
5. I have had very peculiar and strange experiences.
6. I have a cough most of the time.
7. I seldom worry about my health.
8. My sleep is fitful and distrubed.
9. When I am with people I am bothered by hearing very queer things.
10. I am in just as good physical health as most of my friends.
11. Everything is turning out just like the prophets of the Bible said it would.
12. Parts of my body often have feelings like burning, tingling, crawling, or like "going to sleep."
13. I am easily downed in an argument.
14. I do many things which I regret afterwards (I regret things more or more often than others seem to).
15. I attend church almost every week.
16. I have met problems so full of possibilities that I have been unable to make up my mind about them.
17. Some people are so bossy that I feel like doing the opposite of what they request, even though I know they are right.
18. I like collecting flowers or growing house plants.
19. I like to cook.
20. During the past few years I have been well most of the time.
21. I have never had a fainting spell.
22. When I get bored I like to stir up some excitement.
23. My hands have not become clumsy or awkward.
24. I feel weak all over much of the time.

CONTINUE

25. I have no difficulty in keeping my balance in walking.

26. I like to flirt.

27. I believe my sins are unpardonable.

28. I frequently find myself worrying about something.

29. I like science.

30. I like to talk about sex.

31. I brood a great deal.

32. I get mad easily and then get over it soon.

33. I dream frequently about things that are best kept to myself.

34. My way of doing things is apt to be misunderstood by others.

35. I have had blank spells in which my activities were interrupted and I did not know what was going on around me.

36. I can be friendly with people who do things which I consider wrong.

37. If I were an artist I would like to draw flowers.

38. When I leave home I do not worry about whether the door is locked and the windows closed.

39. At times I hear so well it bothers me.

40. Often I cross the street in order not to meet someone I see.

41. I have strange and peculiar thoughts.

42. Sometimes I enjoy hurting persons I love.

43. Sometimes some unimportant thought will run through my mind and bother me for days.

44. I am not afraid of fire.

45. I do not like to see women smoke.

46. When someone says silly or ignorant things about something I know about, I try to set them right.

47. I feel unable to tell anyone all about myself.

48. My plans have frequently seemed so full of difficulties that I have had to give them up.

CONTINUE

49. I would certainly enjoy beating a crook at his own game.

50. I have had some very unusual religious experiences.

51. One or more members of my family is very nervous.

52. I am attracted by members of the opposite sex.

53. The man who had most to do with me when I was a child (such as my father, stepfather, etc.) was very strict with me.

54. Christ performed miracles such as changing water into wine.

55. I think Lincoln was greater than Washington.

56. In my home we have always had the ordinary necessities (such as enough food, clothing, etc.).

57. I pray or meditate several times a week.

58. I feel sympathetic towards people who tend to hang onto their griefs and troubles.

59. I am afraid of finding myself in a closet or small closed place.

60. Dirt frightens or disgusts me.

61. I am made nervous by certain animals.

62. My skin seems to be unusually sensitive to touch.

63. I feel tired a good deal of the time.

64. I never attend a sexy show if I can avoid it.

65. If I were an artist I would like to draw children.

66. I sometimes feel that I am about to go to pieces.

67. I have often been frightened in the middle of the night.

68. I very much like horseback riding.

STOP

Section 4 Introductory Biofeedback Paper (Pre-Training)

DEAR TRAINEE: PLEASE READ THIS CAREFULLY

Congratulations! You have been selected for the final phase of my thesis project: 20 one-hour sessions of biofeedback training. Yes, your thinking style successfully survived the gruelling scrutiny of the computer! And by the way, just to clear the air of all past and future deception, let me explain immediately that the second questionnaire you filled out (the timed one where you said "STOP" and held up your number) had a completely bogus procedure. By that I mean that your actual time was totally irrelevant to your performance- in fact, your time was never computed and was not even recorded that night! I'll explain at the group meeting exactly what was important and why we had to fool you alittle. At any rate, rest assured that that was (and will be) the only bogus aspect of the experiment.

OK, now that you are ready and anxious for the training, let's take a moment to clarify a few things about biofeedback, in the form of questions and answers.

WHAT IS BIOFEEDBACK AND BIOFEEDBACK TRAINING?

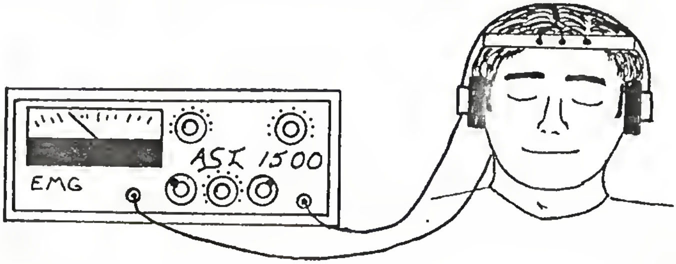
The term biofeedback was coined by a group of psychologists, physiologists, physicians, biomedical engineers, and other professionals at the first Biofeedback Research Society meeting in 1968. As the term implies, biofeedback refers to "feedback" from your "biology." More specifically, it is the process whereby an individual receives continuous information regarding one or more of his ongoing bodily functions. Thus, biofeedback training refers to someone using this continuous biological information to effect a willful change in one of his bodily processes. This is done just like learning to ride a bicycle: through trial and error. Just as you use the "feedback" from the bicycle, your sense of balance, etc. to learn to ride, you use the feedback from your body to learn to gain control over one or more of its physiological processes.

WHAT KINDS OF BODILY ACTIVITY ARE "FED BACK" TO THE TRAINEE AND HOW IS THIS DONE?

As a result of our ever-expanding technological involvements, electronic instruments have been developed which can very accurately monitor the subtle fluctuations of our bodily activity, and which can simultaneously provide us with this information by converting it to a modality which we can perceive with our "normal" senses. Essentially these instruments serve to mirror certain physiological processes of our bodies. For example, the surface activity of the billions of nerve cells in your brain (EEG), which vary in their electrical patterns and are measured in their intensity by microvolts (millionths of a volt), can be converted to a tone you can hear or a light you can see. The tone might vary in pitch according to the frequency or "rate of change" of brain cell activity and might alter in loudness according to the amplitude or "strength" of this brainwave activity. Similarly, the light signal might blink on and off at a rate similar to the brainwave frequency at any moment and vary in brightness according to the amplitude (intensity) of the brain wave activity.

Brain wave activity is, of course, not the only physiological process to which biofeedback can be applied. In fact, any bodily process which is measurable or able to be accurately monitored can be a potential source for biofeedback training. Just a few of these are heart rate, muscle tension (EMG), skin temperature, blood pressure, and the electrical activity of the skin (GSR, SC).

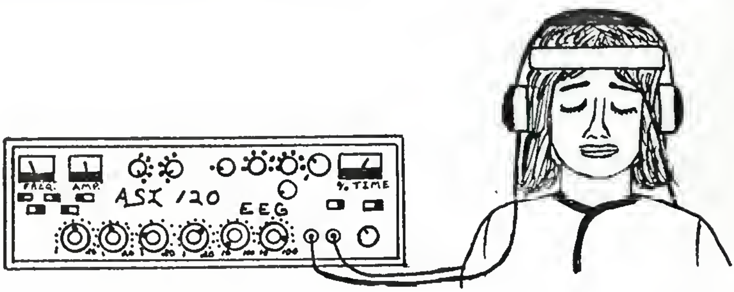
A common EMG (muscle) biofeedback technique involves the placement of surface electrodes on the forehead or frontalis muscle. The instrument will then produce a clicking sound that varies with the amount of muscle tension



in the trainee's forehead: The more tension in the muscle, the faster the clicks; the more relaxed the muscle, the slower the clicks. Therefore, the trainee's task would ordinarily be to try to keep the clicks as slow as possible, thus lowering his muscle tension.

HOW DO YOU DECIDE WHICH PHYSIOLOGICAL PROCESS TO "FEED BACK?"

When biofeedback training is used in clinical application, the choice of which bodily function(s) to "feed back" to an individual varies according to the specific physiological process or processes which are most related to his needs. For example, if a person tenses his muscles too much, EMG biofeedback training may be used to help him learn to relax his muscles more easily. In another example, a person might find that his muscles are relaxed but he nevertheless feels tense. In such a situation, EEG (brain wave) biofeedback training may help, with his task being to increase the occurrence of particular EEG frequencies associated with relaxation. Since these "relaxed"



brain waves happen to be slower than those associated with tension or everyday thinking, the trainee (listening to a musical tone which rises and falls in pitch as his brain waves speed up and slow down) would naturally try to keep the musical tone as low in pitch as possible, thus slowing down his brain waves.

Other choices of physiological processes to feed back might include skin temperature (to increase peripheral blood circulation), heart rate

(to raise or lower heart beat), or blood pressure (to raise or lower blood pressure). Even blood sugar levels and pancreatic secretions (e.g., insulin) have been "fed back" experimentally to help diabetics reduce their need for injections. It should be noted, however, that in the case of pancreatic secretions or rehabilitation of damaged muscles, the biofeedback training involves the reverse of what has been described so far: The trainees are attempting to increase (rather than decrease) their bodily activity. Either way, it is still biofeedback training.

IS BIOFEEDBACK TRAINING SIMILAR TO MEDITATION OR YOGA?

Yes and no. All three techniques may be used as tools toward acquiring greater voluntary control over low arousal (relaxation) states, often for the purpose of neutralizing physical or psychological tension or reducing the effects of psychosomatic conditions. In other words, all three techniques (and many others) have been known to help people learn to relax and deal more effectively with acute and chronic stress.

However, where meditation and yoga utilize passive concentration alone, biofeedback training simultaneously employs electronic instruments which inform the trainee of his ongoing bodily activity. The role of this additional information or feedback cannot be underestimated because (1) the feedback information is an objective index of one's progress during training since it constantly reflects where the trainee is (and where he is not), (2) the feedback is directly related to desirable bodily activity, that is, bodily activity that would ordinarily occur during successful meditation or yoga, and (3) research has shown that the low arousal learning process is enhanced with the implementation of this feedback information, just as learning tennis might be enhanced through the addition of videotape equipment.

BIOFEEDBACK TRAINING IN A NUTSHELL

In summary, biofeedback training, or the learning of psychological states associated with bodily changes, is actually training in becoming

aware. This increased awareness and the feelings associated with it can be used to alter bodily processes to a degree over which we ordinarily have little or no conscious control. The voluntary control over bodily processes and the recognition of conscious states occurring simultaneously involve the development of a skill and is the result of a learning process taking place. This learning process is a direct result of the use of the feedback information from the instrument, very similar to the use of the feedback from your fingers and the sounds that you hear when learning to play the piano. Finally, as with any skill, regular practice is essential.

WHAT IS THE PURPOSE OF THE PRESENT BIOFEEDBACK EXPERIMENT?

As you've been informed thusfar, the present experiment is investigating the individual differences in training among persons who differ markedly in "cognitive style," or generalized thinking patterns. In short, <u>we are interested in the cognitive variables involved in learning voluntary control of physiological process through biofeedback training, rather than the effect of biofeedback training on specific physical or psychological conditions</u>. Consequently, some of you are expected to show different training patterns than others. Neither you nor I (the experimenter), however, will know the actual group to which you were assigned by the computer. This double-blind procedure will prevent experimenter or subject bias from influencing the results of the experiment.

At this point, I must ask you to take on faith the theoretical details of the experiment (e.g., how the "cognitive style" groups are expected to train and why). Until all the data are in, I would appreciate your patience and understanding in remembering to address yourself specifically to the training. Naturally, I will be happy to discuss with you the theoretical hypotheses and results of the study following the final data collection period (i.e., after April 15).

EXACTLY HOW WILL THE BIOFEEDBACK
TRAINING BE CONDUCTED?

Sometime very soon (see attached sheet for date, place and time) all of the biofeedback trainees will meet for a final introductory meeting before the training sessions begin. Please read this paper thoroughly before the meeting. At this time, training procedures will be further explained, the training schedule will be arranged, and all of your questions will be answered (I hope). For scheduling purposes, please be aware of your daily schedule through April 15.

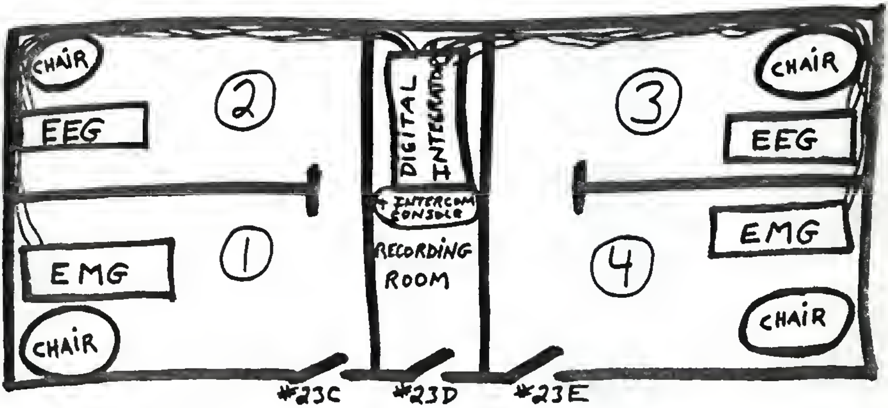
All one-hour sessions (except the upcoming meeting) will be held in Eisenhower Hall (KSU) Room 23. Each trainee will select an hour of the day or evening (9 AM - 8 PM) for his daily training session (Monday through Thursday) starting March 8 for 20 days (excluding week of March 15-19). Each trainee's session will be at the same hour every day.

The lab contains four training rooms, but only two of them can be operational from 9 AM - 5 PM. All four training rooms will be available from 5 PM - 8 PM. In view of this situation, please keep in mind that there are 32 of you, and that flexibility in scheduling on your part may be required. Finally, since scheduling will obviously result in trainees arriving on the hour almost all day and evening, it is essential that each of you BE ON TIME for each of your sessions. The latter request cannot be overemphasized! I don't mean to dwell on this, but significant problems will result if the schedule is not adhered to. Please try to keep your fellow trainees in mind.

The first lab session (March 8) will be entirely introductory. You will each learn how to apply the headband/electrode set and how to operate the biofeedback instrument and intercom module. We will practice these very simple procedures until they are automatic, so that minimal time will be required for this during training sessions.

Since some of you will receive EEG training and some will receive EMG training, depending on the group to which you will be assigned, your

electrode placement will naturally vary. EEG trainees will learn to place the electrodes over either the left or right side of their scalps (i.e., either the left or right hemisphere), while EMG trainees will place the electrodes over their frontalis or forehead muscle. Each of you will have a lapel microphone through which you can communicate with me (or whoever might be the experimenter at the time) when necessary.



Shielded cables will transmit electronic information reflecting your ongoing bodily activity (either EEG or EMG) to the recording room, located centrally among the four training rooms. While you are practicing with the auditory feedback, the digital integrators in the recording room will compute 2 minute averages of either your EEG or EMG activity, and every 4-5 minutes I will inform you via intercom of these values. You should find this verbal feedback very helpful in guiding your responses toward either lower EEG frequency values or lower EMG amplitude levels.

The second,third, and fourth lab sessions(March 9, 10, & 11) will consist of baseline recording, during which time you will be asked simply to relax as you normally would. These three sessions will allow us to calibrate our recording instruments and to get an idea of the nature of your EEG or EMG activity before training begins.

All lab sessions thereafter (March 22 - April 15) will be devoted entirely to training. EEG trainees will attempt to lower the pitch of a musical tone (hence, lowering the dominant frequency of their brain waves) and will receive verbal feedback of averaged 2 minute EEG frequency via intercom. EMG trainees will attempt to slow the click rate of the feedback instrument (hence, lowering the forehead muscle tension) and will receive verbal feedback of averaged 2 minute EMG amplitude.

Finally, if any of these procedures seem complicated, please be assured that they are not. Children as young as 8 years of age are currently undergoing similar biofeedback training procedures quite successfully!

FINAL GUIDLINES

(1) Please call me at 537-8611 or leave a message at 532-6850 AS SOON AS POSSIBLE to let me know you have received this introductory paper.

(2) It is recommended that you inform your personal physician of the training you will be undergoing. This is just a safety precaution in case you are on medication that might need to be modified at some point during training.

(3) Please bring to the meeting a list of any health problems you have, as well as all prescribed medications you are currently using. (Include your subject number, if you remember it.)

(4) It is strongly recommended that you refrain from the use of non-prescription drugs both before and during training. This would include regular use of alcohol, marijuana, aspirin, caffein, etc. The use of such drugs will more than likely impede your training efforts.

(5) Please try to wear loose, comfortable clothing to each session. This will help prevent restriction of blood circulation.

(6) It is requested that you <u>eat or drink nothing</u> except water for at least 1½ - 2 hours before each training session (baseline sessions, also). This especially includes coffee, tea, coca-cola, or other drinks containing caffein.

(7) Please try to get 7-8 hours of sleep per night during the baseline recording and training periods.

(8) Please bring any questions you might have to the group meeting, which has been scheduled for TUESDAY, FEBRUARY 24, EISENHOWER HALL (KSU), ROOM 21, AT 7:00 PM (should take less than an hour). Acquiring this room was a stroke of luck, as it is right next door to the training lab and will allow us to take a quick cook's tour of the facility.

(9) Once again, please be on time for all lab sessions.

(10) Sorry this paper had to be so long---there was a lot to cover!!

Thanks again for your cooperation! Have a nice day- see you Tuesday evening!

Sincerely,

Dale M. Patterson

Section 5 Cognitive/Behavioral Questionnaire (Post-Training)

As I'm sure you well know, you have donated a large amount of your time to biofeedback research, in general, and to my thesis project, in particular. Let me say immediately that this donation was very much appreciated, not only by myself, but also my Thesis Advisor, Dr. Leon Rappoport. In addition, the members of my Supervisory Committee, including Drs. Frederick Rohles, Jerome Frieman, and David Danskin, also wish to express their sincere thanks. The only way we, as investigators, can accurately research and modestly describe human behavior is through voluntary actions such as yours.

Despite the research orientation of this project, it is my hope that your efforts at relaxation training will not be without some observable, personal gain. It is in this regard that the following questions have been prepared for you. They will hopefully serve two purposes: (1) to provide me with feedback regarding resultant behavior changes from, and your feelings about, the experiment, and (2) to allow you an opportunity to attend to the feelings and behaviors which, when altered, could be viewed as potential benefits derived from biofeedback training. In short, we will both receive feedback, which is, of course, just what the experiment is all about!

Again, thank you very much for your diligent cooperation, unfailing attendance, and consistently positive attitude throughout the entire experiment. I hope you enjoyed it as much as I did!

Name ____
(please print or type)

SINCE YOUR BIOFEEDBACK TRAINING BEGAN:

(1) Have you noticed any positive or negative changes in your ability to concentrate on assignments or lectures (i.e., either an increase or decrease in the extent to which unrelated thoughts temporarily distract you)? Do these changes vary according to whether the material is interesting vs. uninteresting, stimulating vs. boring, etc?

(2) Have you noticed any positive or negative changes in your ability to take tests? Changes in feelings or "flow of thought" before, during, or after tests? Changes in the number of careless mistakes?

(3) Have you noticed any positive or negative changes in your voluntary speaking behavior (i.e., raising your hand to ask a question, speeches, etc.) in a large class? Small class? Changes in feelings when speaking in class?

(4) Have you noticed any positive or negative changes in your motivation to get your course assignments done on time? Changes in amount of guilt when not studying? Changes in amount of procrastination or delay before sitting down to study?

(5) Have you noticed any positive or negative changes in your sleeping habits? Time required to fall asleep? Amount of dreaming? Vividness of dreams? Memory of dreams? Feelings about dreams and feelings in the morning after a night's sleep (i.e., rested, eager vs. tired, depressed)? Ability to take a rest during the day and feel refreshed from it?

(6) Have you noticed any positive or negative changes in your general level of energy during the day? In the evening?

(7) Have you noticed any increase or decrease in the amount of non-presecription medications needed (e.g., aspirin, bufferin, tylenol, etc.)? Prescription medications needed?

(8) Have you noticed any increase or decrease in the amount of coffee you consume? No-Doz? Alcohol? Marijuana? Other drugs?

(9) Have you noticed any positive or negative changes in the amount of tension you feel that you work under? Changes in losing your temper? Saying things you wish later you hadn't said?

(10) Have you noticed any positive or negative changes in your feelings about school? Job? Family? Friends?

(11) Have you noticed any positive or negative changes in your ability to recognize cues that you are getting tense? Ability to control your thoughts? Amount of worry over things that happen each day? Amount of worry over whether you'll ever get everything done that you have to?

(12) Have you noticed any positive or negative changes in your tolerance level for petty annoyances (e.g., someone is late to pick you up; car or bicycle breaks down when needed, etc.)?

(13) Have you noticed any increase or decrease in how often you think, deep down inside, that a stranger you meet is better than you are?

(14) Have you noticed any positive or negative changes in your ability to make decisions?

(15) Have you noticed any positive or negative changes in how much you live for the future; that is, how much you look forward to the future vs. feeling that most of the good times were in your past or are in the present activities?

(16) Have you noticed any positive or negative changes in the amount of your daily life that is devoted to doing what has to be done vs. enjoying what you do?

(17) Have you noticed any changes in your amount of optimism or pessimism?

(18) Have you noticed any changes in how often you initiate conversations with strangers when the situation warrants it (e.g., while standing in line, seated in class, in an elevator, etc.)?

(19) Have you noticed any changes in how you feel in conversations with persons either with whom you're not completely familiar or who project a lot of social status? Changes in your style under these circumstances (e.g., interjecting your ideas or experiences vs. listening or getting others to talk more about their ideas or experiences)?

(20) Have you noticed any changes in how frequently you are concerned about what others think of you? During classes? Walking between classes? Studying in the library or public places? Studying by yourself? At meals?

(21) Have you noticed any positive or negative changes as to your behavior being based on other people's expectations vs. how you really feel?

(22) Have you noticed any increase or decrease in the occurrences of the following:

Headaches	Neck Tension	General Tension or Anxiety
Eye Strain	Forehand Tension	Allergies
Teeth Clenching	Backaches	Relaxation
Cramps	Dizziness	

(23) Please describe the strategies you employed (and the successfulness of each) in trying to alter the physiological feedback signal during training. For example, did you try anything different than during the first three baseline sessions? Did you try positioning your head or body in a certain way, or tensing or relaxing certain muscles, or generating certain feelings or emotions? Did you try using visual imagery or your imagination in any way? Did you focus to a greater or lesser degree either internally or externally? Did you try using systematic, logical, or analytic strategies of any kind? Did you try thinking particular thoughts, or perhaps thinking nothing at all? Did you try other strategies not mentioned (please elaborate)?

(24) Finally, please describe your experience in the experiment: Describe in detail what you liked most and least about the experiment. What things did we do that really appealed to you or really turned you off? List pros and cons, stresses and strains, rewards and frustrations. Last but not least, please list any suggestions relevant to future experiemnts that we might consider.

THANK YOU VERY MUCH FOR YOUR TIME AND EFFORT--IT IS VERY MUCH APPRECIATED!

APPENDIX D

BIOFEEDBACK TASK VARIABLES

Section 1 Factors Underlying Successful Training

Most subjects (i.e., 22 of 32) in this investigation gained voluntary control (as defined in Appendix A, Section 1) of the physiological process presented to them via an auditory feedback stimulus reflecting the ongoing activity of that process. Without laborious consideration of the many, perhaps insolvable issues underlying "true" operant conditioning (Appendix A, Section 2), it is concluded that learning took place during the experiment.

Apparently contributing to such learning was, in the case of the EEG subjects, the use of a frequency-controlled, continuous-analog, auditory feedback stimulus, in contrast to a binary stimulus dependent upon both amplitude level and frequency band (i.e., continuous dominant frequency feedback *vs.* alpha or theta feedback).

Although the independent effects of continuous-analog *vs.* binary feedback were not compared in the present study, recent evidence has indicated that the former mode of feedback is more effective than the latter in eyes closed EEG training (cf. Travis *et al.*, 1974). These authors concluded that the "on-off" characteristic of binary feedback tends to be distractive during training relative to the continuous, variable-pitched, analog type. Moreover, the utility of such a feedback stimulus exemplifies the brain's extraordinary capacity for response specificity, as described by Schwartz (1975).

More specifically, the brain appears to be a highly efficient organ capable of recruiting and coordinating only those physiological processes needed to perform a given task. For example, while rewarding subjects for increasing or decreasing individual motor unit output within a specific muscle, Basmajian (1972) found that adjacent motor units in the muscle are initially activated but subsequently drop out as training progresses.

In this connection, the failure in the present study of either trained hemisphere's amplitude and alpha activity to reliably covary across sessions along with frequency decrements probably relates to this response specificity of the brain. Specifically, it is suggested that amplitude levels in the trained hemisphere may have been "recognized" as irrelevant to the task, and were thus not changed reliably during frequency training.

Perhaps also contributing to the learning effects found in this experiment was the regular use of verbal feedback during training (cf. Hart, 1968). Although Kinsman et al. (1975) reported that discrete posttrial verbal feedback did not reliably augment the effect of continuous-analog, auditory feedback during training, their study examined only frontalis EMG feedback stimuli. Moreover, as in the present study, frontalis EMG feedback stimuli (alone) in their study facilitated the attainment of extremely low levels of frontalis muscle tension, such that a ceiling effect could be invoked as an explanation for the above finding. Therefore, the relatively few reliable trend components across sessions displayed in the present study by successful EEG groups (cf. Hardt, 1975; Harrison & Raskin, 1976), and the numerous reports of these subjects that verbal feedback served as a "useful frame of reference" during training, indicate that such feedback was probably an important component of the training process.

But what is actually being learned during such training? The present

investigation has maintained (and, to a certain extent, demonstrated) that the reinforcement and potential acquisition of a passive set resembling the spatial-intuitive cognitive mode is occurring.

Section 2 Task Difficulty

A key factor in attempting to interpret the findings of this study is that low arousal EEG training was far more difficult for the subjects than low arousal EMG training. For example, EMG groups reduced their frontalis amplitude from baseline by an average of 41%, whereas EEG groups reduced their dominant frequency from baseline by an average of 7%. Assuming that (1) no differences existed in the information delivered by the feedback stimuli, and (2) cognitive factors were instrumental during training, interpretation of training differences by cognitive style must include reference to the fact that success in EEG training required greater "cognitive effort" than success in EMG training.

It is widely acknowledged among biofeedback researchers and clinicians that EEG training (usually alpha or theta control) is more difficult than low arousal EMG training, since the skeletal muscles are, in general, under much greater voluntary control than cortical potentials. However, to the author's knowledge the question of relative task difficulty has not been systematically examined.

Thus, although "cognitive effort" (i.e., task difficulty) was found to be unrelated to task lateralized asymmetry (Dumas & Morgan, 1974) per se, it does appear to be related to volitional EEG frequency decrement, in general, and cognitive style, in particular. Finally, this variable also appears to interact with the combination of the trainee's cognitive style and trained hemisphere's lateralized function (i.e., aligned *vs.* unaligned).

More specifically, where the subject's cognitive style does not match

his trained hemisphere's lateralized function (i.e., training in "non-preferred" hemisphere), the biofeedback task is more difficult for at least one of the training variables examined (e.g., rate of frequency reduction). Thus, from the data presented in Chapter 3, it appears that a subject has greater voluntary control over rate of frequency reduction when training from his "preferred" than from his "non-preferred" hemisphere. As indicated, however, for spatial-intuitive subjects this enhanced voluntary control is not reliable for amount of frequency decrement.

Section 3 Electrophysiological Correlates (Low Arousal)

A final point concerns the electrophysiological correlates of the low arousal biofeedback task, viz., whether it is a right *vs*. left hemisphere-mediated task. For example, the right hemisphere has been implicated as the primary mediator of hypnosis (Morgan *et al*., 1974; Bakan, 1971) and meditation(Frumkin & Pagano, 1976). Since these activities are similar in effect to low arousal biofeedback training, it appears reasonable to suggest that the latter task may also be right hemisphere-mediated.

Along this line, Galin and Ornstein (1972, 1974), Ornstein (1973), Galin (1974), and Robbins and McAdam (1974) have demonstrated that a hemisphere-specific task results in decreased amplitude and alpha activity in the ipsilateral hemisphere and increased amplitude and alpha activity in the contralateral hemisphere. Thus, if biofeedback training (i.e., dominant EEG frequency reduction) is a *bona fide* right hemisphere task, as suggested, then amplitude and alpha activity during the task should increase in the left hemisphere and decrease in the right, regardless of which hemisphere is trained.

Although bilateral recording was not employed in the present investigation, indirect evidence for low arousal EEG biofeedback training as a

right hemisphere-mediated task is illustrated graphically in Figures 8 and 9 (see Chapter 3). These data show that the left hemisphere training groups (e.g., LHSI, LHVA) displayed increasing amplitude and alpha activity from baseline across sessions, while right hemisphere training groups (e.g., RHSI, RHVA) displayed decreasing amplitude and alpha across sessions. Although these changes were not statistically reliable, they become meaningful when examined together and in view of the excessive amount of variability and instability present in these data (probably due to inadequate controls for bodily movement) and the small number of subjects within each hemisphere group.

Moreover, if the influence of the brain's "preference" for response specificity is correct (see Schwartz, 1975), this would tend to reduce the probability that amplitude (and thus alpha) activity within the ipsilateral (i.e., trained) hemisphere will change reliably during a task utilizing a frequency-controlled feedback stimulus.

Thus, although bilateral recording is required before unequivocal statements can be made, the trends of both amplitude and alpha activity across sessions found among the left and right hemisphere groups provide some support for low arousal EEG biofeedback training as a right hemisphere-mediated task.

APPENDIX E

METHODOLOGICAL ISSUES

While the present investigation has offered some insight into the relationship between low arousal biofeedback training and cognitive style, it is not without its shortcomings. Although some of these problems have been reviewed earlier or alluded to throughout the text, the more important ones will be considered and briefly discussed below.

Questionnaires. The most serious problem involves the nature of the cognitive preference measuring instruments used, as described in an earlier section. Generalization of the results of the present study becomes extremely limited, for example, when it is recalled that the best predictor of performance in training is a questionnaire oriented specifically to undergraduate students concerning their choice of a college major. It would be extremely useful, in the author's opinion, to reconstruct Baumgardner's Intuitive-Analytic Questionnaire using more general questions eliciting cognitive strategies toward life experiences in a much broader context. Replication of these results using such a questionnaire, as well as a more representative sample, would thus allow far greater generalization.

A related problem involves the use of a perceptual response measure, along with the general, cognitive preference questionnaire, in order to dichotomize cognitive style groups of interest. Since the two measures used here (e.g., Baumgardner's questionnaire and Galin and Ornstin's spatial-verbal measure) did not correlate in either direction, and since the spatial-verbal

measure did not adequately dichotomize "spatial responders" and "verbal responders," the relationship between generalized cognitive strategies and descriptively similar perceptual response tendencies remains somewhat ambiguous.

It would thus appear useful to perform replications of the present study using each measure as a separate independent variable, in order to determine which measure's set of extreme scores accounts for the largest proportion of variance during training. Moreover, separate groups could be trained on the basis of composite scores on these and other measures (e.g., Rotter's I-E scale), as well, to gain further insight into the relationships between them and their respective ability to predict performance in training. In addition, controls for anxiety level should be included where Barron's Ego Strength Scale is used, as discussed earlier.

Parenthetically, it would also appear useful to include a perceptual response measure which accounts for our cultural bias toward verbal-analytic activity by using a larger number of carefully selected spatial items. However, the best control for this problem appears to be the use of extreme, occupationally-matched training groups (cf. Galin and Ornstein, 1974).

Further, reliability and validity coefficients were not available for the measures used in the present study. In order to ensure measurement of what is intended to be measured, as well as confidence that such measurement within subjects will be similar on different occasions, the questionnaires used should have validity and reliability coefficients equal to or greater than those commonly found in the psychological literature.

Finally, and most important, the use of extreme questionnaire scores

themselves precludes to a certain extent meaningful generalization of empirical results found within individual difference studies. Whether it is biofeedback training or some other behavior under investigation, the use of extreme scores in behavioral prediction eliminates from potential generalization a major portion of any population sampled. Although useful for identifying and investigating the predictive correlates of the behavior under study, the utility in prediction of that behavior via extreme questionnaire scores is obviously limited to the existence of those who meet such stringent criteria. Such predicitve utility would appear to be particularly limited where the target behavior is highly specific (e.g., EEG frequency reduction vs. biofeedback training, in general). These "facts of life" are central to the scientific process and should be kept in mind where the practical application of such research is concerned.

Baseline recording/biofeedback training. Returning to the role of the resting EEG differences by cognitive style found in the present study, the question must now be asked: What proportion of the training differences found between SI and VA groups can be attributed to these pre-training differences? In attempting to answer this question, a related question arises: Are the SI curves in Figure 6 (see Chapter 3) reflective of learning or some other process, such as habituation? That is, can group training effects and/or training differences found during the experiment be attributed to a gradual, naturally occurring return of EEG activity to basal levels?

Inferring that the reduction of frequency seen in both the LHSI and RHSI groups is due to habituation requires an explanation as to why similar frequency reduction did not occur in the LHVA and RHVA groups. That is, one would need to postulate that SI subjects were preferentially sensitized

(i.e., aroused) by the experimental situation while VA subjects were not. In the absence of any experimental evidence to confirm this idea, the utility of a post hoc rationale such as this appears questionable.

However, in the interest of closure, it will be noted that certain aspects of the EEG data themselves argue against habituation among SI subjects being solely responsible for the differences found among the hemisphere training curves in Figure 6. For instance, the baseline data presented in Table 2 do not seem to support this idea (e.g., see LHSI group on the IF variable). That is, if habituation was manifested via a steady frequency reduction, as might be expected, such a reduction should be visible in the baseline data for this group across time. As can be seen, although habituation to the experimental situation was undoubtedly occurring during the baseline sessions, it appears that such habituation was not directly apparent in terms of steady frequency reduction. Thus, one cannot reasonably state that the decrements in the frequency curve across training sessions for this group were due to habituation.

Moreover, the amplitude and alpha index data also argue against habituation (see Figures 8 and 9). Onset of a novel stimulus produces desynchronization (i.e., a frequency increase) in the cortical EEG, along with a reduction in amplitude. This cortical response is also called alpha blocking (Thompson, 1967) and is inversely related to the alpha index measure used in the present study. That is, a reduction in the amount of alpha blocking leads to an increased alpha index (i.e., per cent time alpha). Thus, bona fide habituation should be observable via an increase in the alpha index across sessions.

The alpha index values for each group presented in Figure 9, and these values for the LHSI group, in particular, are informative in this regard.

For instance, although the increase in alpha index seen in the first three training sessions could be reflective of habituation, Sessions 4-6 show a slight reduction in alpha index. This decrease in alpha becomes important when it is recalled that the first reliable reduction of frequency (from baseline) among LHSI subjects was found at Session 6 (see Figure 6). Thus, frequency reduction continued in spite of the fact that habituation, by definition (i.e., increased alpha index), was not occurring. Further, the second reliable reduction of frequency (from Session 6) for this group was found at Session 15, also in the absence of any appreciable increase in alpha index.

Although in a strict sense the question of habituation can be definitively answered only via the inclusion of yoked-control groups, the aspects of the data discussed above appear to argue effectively against habituation as having played a major role in the EEG training results of the present study. Consequently, on the basis of this evidence, EEG training effects and training differences found between SI and VA groups cannot unambiguously be attributed to the baseline differences found between them prior to training.

Electrophysiological recording. A common problem among electrophysiological studies concerns extensive variability in the data due to internal and external sources of interference. The latter source usually originates from electrical interference in the area surrounding the trainee, while the former comes from bodily movement of the subject himself.

The present study lacked sophisticated controls for both of these sources of variability. Although dominant EEG frequency recording is relatively immune to bodily movements by the subject,[22] EEG amplitude, alpha, and EMG amplitude certainly are not. Thus, replications of the

present study should include electrically-shielded training rooms, if possible, and recording procedures which eliminate or minimize bodily movement during training. In addition, EOG and EMG activity from a number of key facial and upper body locations should be concomitantly obtained so that artifacts in the EEG can be more accurately detected and subsequently deleted.

A second problem with the present study concerns the lack of bilateral EEG recording employed. As discussed earlier, this type of recording, preferably from a number of independent, homologous leads, would reveal the activity of both hemispheres at a wide variety of scalp locations during training. This additional data, preferably analyzed on-line by a computer, would be indispensable in making inferences concerning relative hemisphere activation by electrode placement during both baseline and training sessions. Thus, the specific roles of each hemisphere for each subject during "normal relaxation" and self-regulated, biofeedback training can be completely understood only by employing such recording techniques.

Finally, in the interest of testing the theoretical rationale offered by Schwartz (1975), multi-system recording during training, along with reliable cognitive/subjective measures during and following training, should be employed whenever possible.

APPENDIX F

SEX DIFFERENCES

Although no specific training differences were noted between the sexes in the present study, a number of differences in cognitive style and baseline physiology were found. These differences are summarized in Table 8.

Table 8 about here

The role of sex differences in both cognitive style and performance in tasks requiring one or both cerebral hemispheres appears to be giving way to a more salient, biological variable: maturation rate. In reviewing the literature, inconsistency among studies investigating sex differences in cognition seems to be the rule rather than the exception. For example, Nash (1970) concluded that females are superior to males in verbal skills and tasks requiring language and memory, while males are superior to females in arithmetic/numerical skills and tasks requiring spatial and conceptual functioning. In contrast, Kagan et al. (1963) reported that males are superior to females in sequential or "analytic" functioning and that females are superior to males in tasks requireing global or "relational" processing.

Experiments which have examined hemispheric specialization by sex have been equally unenlightening. For example, college females have been shown to shift to greater right hemisphere activation (thus, evidencing greater lateral asymmetry) during self-generated tasks requiring right hemisphere mediation, while males were found to display reliably less lateral asymmetry during such activity (Davidson, Schwartz, Pugash, & Bromfield, 1975;

Davidson & Schwartz, 1976). However, Levy and Reid (1976) found that females, in general, show less laterality than males and Herron, Galin, and Ornstein (1976) found sex differences by task only within the left hemisphere.

Thus, studies investigating individual differences in both cognitive abilities and lateral asymmetry by sex have provided inconclusive results. With this in mind, two independent developmental studies appear to offer some insight into this dilemma. The first study (of 200 children) found that boys, as early as age 6, showed a unilateral (right hemisphere) specialization for tasks found to be right hemisphere-mediated in adults, while girls, up to age 13, showed a bilateral representation while engaged in the same task activities (Witelson, 1976). The second study found that early maturing adolescents performed better on verbal than spatial task activities, regardless of sex, while late maturing ones showed the opposite pattern (Waber, 1976).

Thus, while Witelson's (1976) study supports the view that males are superior to females in spatial (i.e., right hemisphere) ability (cf. Nash, 1970), Waber's (1976) study attempts to account for that difference in terms of differntial maturation rates:

> The striking relation between rate of physical maturation (independent of sex) and spatial ability, verbal-spatial patterns, and lateralization has several important implications. First, sex accounted for only a very small proportion of the variance in comparison to maturational rate. Therefore, reported sex differences in these behaviors probably reflect the differential distribution of the sexes along a physiological continuum more than a categorical difference between male and female. Second, since maturational rate was shown not to be related to verbal ability, the sex differences in verbal and spatial abilities may have very different etiologies and cannot be explained by a common set of causes, whether environmental or constitutional (p. 573).

Taken together, these studies suggest that maturation rate, sex, and neural organization interact in a complex manner to produce overt differences

in cognitive abilities and laterality. In this connection, the finding of the present study that females were associated with intuitive scores and males with analytic scores, for example, becomes difficult to interpret in the absence of additional data for these subjects concerning maturation rate and more specific neural organization.

Therefore, it is felt that meaningful interpretation of the sex differences in cognitive style and baseline physiology found in the present study would require strong qualification and is not likely to be accurate based on available data. Consequently, until results of additional studies examining the roles of maturation rate, cognition and neural organization become available, such interpretation is best not attempted.

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FOOTNOTES

[1]The term "cognitive style" is used for the purpose of conversational convenience only. Definitions of the specific modes of cognition referred to by this term in the present study are delineated in Chapter 1.

[2]"Greater degree of control" (low arousal) is defined as reliably greater reductions of mean EEG frequency or EMG amplitude from pre-training baseline levels by one group _vs._ another.

[3]It should be noted that this statement contains a different procedural implication than earlier references to this point (see Hypothesis 2). Without assuming a correlation, it is reasoned that Es scores should meaningfully distribute themselves among carefully selected spatial-intuitive and verbal-analytic subjects such that relatively high and low ego strength individuals are discernible. More succintly, it was operationally impossible to include independent (matched) groups of high and low ego strength subjects in the present investigation (see Chapter 2).

[4]These terms are used for convenience only, referring more accurately to differential lateral asymmetry shown during spatial-holistic _vs._ verbal-analytic cognitive functioning (see Galin & Ornstein, 1974; Doyle _et al._, 1974; Patterson, 1975).

[5]Temporal recording sites have been chosen (along with occipital) due to their reported functional and anatomical relevance (see Doyle _et al._, 1974).

[6]Subjects from introductory psychology classes received credit for their participation. Local residents were obtained via a notice in the community newspaper, while university students were obtained through a similar notice in the campus newspaper and by seeking volunteers within a number of large classes.

[7]Available instrumentation required that computing intervals for amplitude averaging and alpha index (here defined as the percentage of 8-13 Hz activity between 20-80μV, peak-to-peak) were less than the length of an entire session (i.e., 33.3 minutes).

[8]The first session (55 minutes) was entirely introductory (i.e., no baseline recording or training).

[9]EEG trainees required more assistance in mastering the electrode attachment technique than EMG trainees. It should be noted, however, that the experimenter verified each electrode application, placement, and attachment impedance (regardless of feedback mode) before initiating each baseline or training session.

[10]These instructions were repeated before each of the three baseline sessions.

[11]EMG trainees received average integrated amplitude summaries, while EEG trainees received average integrated frequency, amplitude, and alpha index summaries.

[12]The statistical criterion for rejection of the null hypothesis was maintained at the .05 level of probability. However, the specific probability level obtained for each result is presented for the reader's information.

[13]In all cases, the means in this analysis represented per cent change in a negative direction.

[14]It should be noted that the ANOVA assumption of homogeneity of variances was violated in this analysis (Bartlett's $x^2(.001,63)=205.24$). Moreover, square root, arc sine, and log transformations failed to produce equal cell variances. Therefore, as Lindquist (1953) recommends, significance/confidence levels should be adjusted as follows: For 7-8% Type I error probability, required p is .05; for 5% Type I error probability, required p is .025; for 2% Type I error probability, required p is .01.

[15]R_{ns} = range of non-significance for Duncan's Multiple Range Test.

[16]Time restrictions did not permit statistical evaluation of this difference beyond that presented. Thus, the statement that LHSI subjects displayed reliably higher frequency at every session cannot be made at this time.

[17]It should be noted that the criterion for concluding differential rates of change in this analysis suffers from a logical inconsistency. More specifically, concluding that the RHSI group trained at a greater rate than the LHSI group on the basis of Session 3 vs. Session 6 reductions from baseline, respectively, implies an inappropriate comparison relative to concomitant conclusions drawn with respect to differential amounts or degrees of training for these groups. Moreover, a significant Group x Sessions interaction obtained via a separate ANOVA performed only on these subjects would appear to be the more desirable outcome on which to base such a conclusion. Thus, in the absence of such an analysis, the statistical significance of this finding (and its interpretation) remain questionable.

[18]Since all but one of the SI-EMG subjects trained successfully, the negative relationship found between I_mA baseline scores and individual training was not meaningful (see Table 7).

[19]For more detailed discussions of this issue, see Green and Green (1973a; 1973b; 1974a; 1974b; 1975).

[20]This phenomenon is attributed not only to the relatively recent development of language and complex linear thinking in man's evolution, but also to Western culture's pervasive reinforcement of such behavior. As such, the "dominant" hemisphere is the one which becomes active

electrophysiologically during these emphasized behaviors and the "non-dominant" hemisphere is the one which remains relatively less active and more often "at rest." Thus, greater amounts of "restful" EEG (i.e., alpha or lower dominant frequencies) will be found in the non-dominant hemisphere particularly among persons having genetic heritage and environmental conditioning within Western culture.

[21]See also Schwartz et al. (1975) and Davidson, Schwartz, Pugash, and Bromfield (1975).

[22]This can be seen in the variability of the frequency scores obtained in the present study, which was considerably less than in both the amplitude and alpha scores (see Table 2).

Table 1

Ranges, Means and S.D.s on Baumgardner's (1973) Intuitive-Analytic (IN-AN) Questionnaire, Galin and Ornstein's (1974) Cognitive Style (S: Spatial; V: Verbal) Preference Test and Barron's (1956) Ego Strength (Es) Scale for the First Sample, Initial Selection, Second Sample and Third Sample

	IN-AN			S			V			Es		
	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
FIRST SAMPLE (N=693)												
Volunteers	-25-41	9.35	10.25									
INITIAL SELECTION Intuitive-Analytic (n=300)	-25-41	9.56	14.08									
Intuitive (n=150)	16-41	22.70	5.32									
Analytic (n=150)	-25-2	-3.58	4.68									
SECOND SAMPLE Intuitive-Analytic (n=195)	-25-41	9.60	12.35	4-52	12.06	7.12	11-61	55.49	7.58	30-58	45.33	5.92
Intuitive (n=96)	18-41	20.63	6.12	4-52	11.69	6.84	11-61	55.86	7.12	30-58	45.31	6.70
Analytic (n=99)	-25-2	-1.09	5.57	5-44	12.42	7.39	19-61	55.12	8.02	31-56	45.34	5.09
THIRD SAMPLE Spatial-Intuitive Verbal-Analytic (n=32)	-25-33	7.56	17.90	6-30	13.44	6.54	38-61	54.44	6.32	33-58	44.41	5.85
Spatial-Intuitive (n=16)	18-33	23.50	3.86	12-30	18.12	6.14	38-56	49.75	5.91	33-58	45.18	7.12
Verbal-Analytic (n=16)	-25-4	-9.06	6.67	6-11	8.56	1.31	58-60	59.13	0.88	34-50	43.62	4.31

Table 2

Baseline Frequency (IF), Amplitude (I_eA) and Alpha (AI) for Each Experimental EEG Group and Baseline Amplitude (I_mA) for Each Experimental EMG Group

EXPERIMENTAL GROUP	DEPENDENT VARIABLE	DAY 1	DAY 2	DAY 3	MEAN	S.D.
SI-EEG (n=8)	IF[a]	11.10	11.63	10.74	11.16	1.76
	I_eA[b]	34.38	38.00	32.25	34.88	5.32
	AI[c]	36.88	37.00	50.25	41.38	17.65
VA-EEG (n=8)	IF	9.89	9.78	9.97	9.88	1.27
	I_eA	36.88	36.88	36.25	36.67	11.24
	AI	58.25	54.25	47.88	53.46	23.07
LH (n=8)	IF	10.35	10.61	10.35	10.44	2.01
	I_eA	36.63	38.25	34.88	36.58	10.73
	AI	49.38	43.75	43.38	45.50	25.59
RH (n=8)	IF	10.65	10.80	10.36	10.60	1.27
	I_eA	34.63	36.63	33.63	34.96	6.31
	AI	45.75	47.50	54.75	49.34	16.22
LHSI (n=4)	IF	11.48	12.14	11.81	11.81	2.07
	I_eA	31.25	39.50	27.75	32.83	6.13
	AI	28.75	31.50	25.50	28.58	16.31
RHSI (n=4)	IF	10.72	11.12	9.66	10.50	1.38
	I_eA	37.50	36.50	36.75	36.92	4.16
	AI	45.00	42.50	75.00	54.17	5.23
LHVA (n=4)	IF	9.21	9.08	8.89	9.06	0.58
	I_eA	42.00	37.00	42.00	40.33	13.91
	AI	70.00	56.00	61.25	62.42	22.43
RHVA (n=4)	IF	10.57	10.48	11.05	10.70	1.37
	I_eA	31.75	36.75	30.50	33.00	8.08
	AI	46.50	52.50	34.50	44.50	22.90
SI-EMG (n=8)	I_mA[d]	1.46	1.81	1.60	1.62	0.78
VA-EMG (n=8)	I_mA	1.78	1.72	1.88	1.80	0.53

[a] measured in Hz

[b] measured in uV (p-p)

[c] per cent alpha (8-13 Hz, 20-80 uV)

[d] measured in uV (p-p)

Table 3

Summary of Support for Degree of Training and Rate of Training Components of Each Experimental Hypothesis

EXPERIMENTAL HYPOTHESIS		TRAINING COMPONENT DEGREE OF REDUCTION*	RATE OF REDUCTION
1.	SI > VA	-	-
2.	High Es > Low Es	-	-
3.	SI = High Es	+	+
4.	VA = Low Es	-	-
5.	(a) RHSI > LHSI	-	+
	(b) RHSI > LHVA	+	+
	(c) RHSI > RHVA	+	+
6.	(a) LHSI > LHVA	+	+
	(b) LHSI > RHVA	+	+
7.	LHVA = RHVA	+	+
	Subtotals:	6+, 4-	7+, 3-

Totals: 13+, 7-

*+ denotes support
 - denotes non-support

Table 4

Post-Test and Change Scores for the Intuitive-Analytic (IN-AN) Questionnaire and Ego Strength (Es) Scale

EXPERIMENTAL GROUP	IN-AN POST-TEST MEAN	IN-AN POST-TEST S.D.	IN-AN CHANGE MEAN	IN-AN CHANGE S.D.	Es POST-TEST MEAN	Es POST-TEST S.D.	Es CHANGE MEAN	Es CHANGE S.D.
Third Sample (SI-VA) (n=32)	10.93	14.29	3.71	9.13	44.68	5.26	0.28	3.84
SI (n=16)	23.00	6.00	-0.50	6.17	46.12	4.82	0.93	3.37
VA (n=16)	-1.12	8.70	7.93	9.81	43.25	5.43	-0.37	4.27
EEG (n=16)	10.00	12.74	3.93	9.17	45.50	4.50	0.06	2.90
EMG (n=16)	11.87	16.05	3.50	9.38	43.87	5.96	0.50	4.69
SI-EMG (n=8)	24.87	6.31	0.62	4.53	46.25	4.36	1.37	3.58
VA-EMG (n=8)	-1.12	11.24	6.37	12.22	41.50	6.65	-0.37	5.70
SI-EEG (n=8)	21.12	5.40	-1.62	7.63	46.00	5.55	0.50	3.33
VA-EEG (n=8)	-1.12	5.98	9.50	7.17	45.00	3.46	-0.37	2.55
LHSI (n=4)	17.75	4.27	-4.00	6.97	44.00	2.44	1.50	3.10
RHSI (n=4)	24.50	4.43	0.75	8.50	48.00	7.43	-0.50	3.69
LHVA (n=4)	-2.75	5.56	6.50	1.29	44.00	2.94	-0.25	2.36
RHVA (n=4)	0.50	6.75	12.50	9.71	46.00	4.08	-0.50	3.10
LH (n=8)	7.50	11.88	1.25	7.28	44.00	2.50	0.62	2.72
RH (n=8)	12.50	13.87	6.62	10.52	47.00	5.65	-0.50	3.16

Table 4
(Continued)

EXPERIMENTAL GROUP	IN-AN POST-TEST MEAN	IN-AN POST-TEST S.D.	IN-AN CHANGE MEAN	IN-AN CHANGE S.D.	Es POST-TEST MEAN	Es POST-TEST S.D.	IN-AN CHANGE MEAN	IN-AN CHANGE S.D.
Males (n=17)	8.29	15.36	3.94	7.32	46.82	4.72	0.41	2.93
Females (n=15)	13.93	12.81	3.46	11.10	42.26	4.90	0.13	4.77
High Es (n=16)	11.56	14.53	3.31	7.88	48.44	3.36	-0.56	2.78
Low Es (n=16)	10.31	14.49	4.12	10.48	40.94	3.99	1.12	4.61

Table 5

Summary of Multiple Regression and t-Test Analyses on Each Subject's Feedback-Contingent and Non-Feedback Contingent Dependent Variables

EXPERIMENTAL GROUP/SUBJECT	FEEDBACK-CONTINGENT DEPENDENT VARIABLES (EEG- IF; EMG- I_mA)			NON-FEEDBACK CONTINGENT DEPENDENT VARIABLES (EEG- I_eA)			NON-FEEDBACK CONTINGENT DEPENDENT VARIABLES (EEG- AI)		
	F^a	t_1^b	t_2^c	F	t_1	t_2	F	t_1	t_2
LHSI									
A.D.	6.55	2.44	3.56*	3.20	-2.38	-1.96	2.97	-20.54	-0.91*
L.B.	3.54	3.60	2.78*	0.24	-1.67	-0.41	1.12	1.10	1.62
J.D.	15.84	3.87	4.83*	11.41	-0.92	0.38*	2.13	-8.49	-0.92*
M.J.	0.18	2.62	1.06	1.85	-7.88	-7.59*	0.95	-3.43	-3.40*
RHSI									
J.H.	21.40	1.76	2.35*	0.62	-0.82	-1.19	1.68	-2.19	-1.72
S.B.	2.09	0.20	-0.14	0.93	0.26	0.38	1.44	0.32	0.04
G.B.	1.13	3.00	1.12	3.18	1.89	3.39	3.02	8.18	2.64
S.C.	1.81	9.64	4.10*	3.24	2.39	2.62	0.08	-0.87	-0.19
LHVA									
M.P.	0.28	1.06	0.42	0.03	-1.67	-0.28	0.42	0.33	0.43
M.S.	1.93	2.51	3.55*	0.86	-2.67	-0.41	0.37	0.42	1.29
L.I.	4.45	1.26	2.45*	2.73	2.37	2.25	7.54	1.21	2.13*
G.W.	1.19	0.48	0.43	2.33	-0.75	-1.38	0.01	-0.62	0.02
RHVA									
J.S.	1.88	-0.67	-0.79	1.84	0.88	1.08	11.27	2.42	3.52*
R.S.	1.65	0.81	0.22	0.21	1.00	0.20	0.72	1.23	0.58
S.D.	0.47	1.23	1.14	1.40	-3.05	-1.15	0.62	-0.71	-0.99
M.W.	0.76	6.55	1.58*	3.15	-2.69	-1.54	0.12	-1.22	-0.86
SI-EMG									
J.J.	4.59	1.23	2.18*						
S.S.	7.41	2.09	3.26*						
L.C.	25.85	3.98	4.04*						
D.E.	49.89	7.05	5.73*						
B.M.	45.29	11.93	6.00*						
C.K.	13.61	3.64	2.51*						
W.P.	1.91	1.55	1.29						
J.A.	32.62	18.66	5.64*						

Table 5

(Continued)

EXPERIMENTAL GROUP/SUBJECT	FEEDBACK-CONTINGENT DEPENDENT VARIABLES (EEG- IF; EMG- I_mA) F[a]	t_1[b]	t_2[c]	NON-FEEDBACK CONTINGENT DEPENDENT VARIABLES (EEG- I_eA) F	t_1	t_2	(EEG- AI) F	t_1	t_2
VA-EMG									
S.B.	28.54	4.00	2.84*						
R.W.	1.43	0.27	0.56*						
R.G.	22.99	2.91	2.33*						
J.S.	6.67	3.41	4.09*						
M.T.	31.34	2.20	2.32*						
B.S.	63.59	16.31	5.12*						
D.B.	17.69	5.32	7.05*						
S.B.	20.71	4.05	3.20						

[a] regression component: $F_{cr}(.05,2/14)=3.74$

[b] t-test (early vs. late pairs): $t_{cr}(.05,2)=4.30$

[c] t-test (early vs. late triplets): $t_{cr}(.05,4)=2.78$

*denotes reliable regression component and/or reliable difference between early and late training sessions

Table 6

Change Scores on the Intuitive-Analytic (IN-AN) Questionnaire and Ego Strength (Es) Scale for All Experimental Groups as a Function of Success in Training

EXPERIMENTAL GROUP	IN-AN CHANGE		Es CHANGE	
	TRAINED	UNTRAINED	TRAINED	UNTRAINED
ALL SUBJECTS	+2.4 (n=22)	+6.6 (n=10)	+0.73	-0.70
SI	-0.75 (n=12)	+0.25 (n=4)	+1.60	-1.00
VA	+6.20 (n=10)	+10.80 (n=6)	-0.30	-0.50
EMG	+3.60 (n=14)	+2.50 (n=2)	+0.29	+2.00
SI-EMG	+1.60 (n=7)	-6.00 (n=1)	+1.40	+1.00
VA-EMG	+5.70 (n=7)	+11.00 (n=1)	-0.86	+3.00
EEG	+0.25 (n=8)	+7.60 (n=8)	+1.50	-1.40
SI-EEG	-4.00 (n=5)	+2.30 (n=3)	+1.80	-1.70
VA-EEG	+7.30 (n=3)	+10.80 (n=5)	+1.00	-1.20
LH	-1.80 (n=5)	+6.30 (n=3)	+1.40	-0.67
RH	+3.70 (n=3)	+8.40 (n=5)	+1.70	-1.80
LHSI	-7.00 (n=3)	+5.00 (n=1)	+2.00	0.00
RHSI	+0.50 (n=2)	+1.00 (n=2)	+1.50	-2.50
LHVA	+6.00 (n=2)	+7.00 (n=2)	+0.50	-1.00
RHVA	+10.00 (n=1)	+13.30 (n=3)	+2.00	-1.30
MALES	+2.60 (n=11)	+6.50 (n=6)	+1.30	-1.20
FEMALES	+2.30 (n=11)	+6.80 (n=4)	+0.18	0.00
MALES (EEG)	+4.60 (n=5)	+5.60 (n=5)	+1.20	-2.00
FEMALES (EEG)	-7.00 (n=3)	+11.00 (n=3)	+2.00	-0.33
HIGH Es	+2.60 (n=11)	+4.80 (n=5)	+0.18	-2.20
LOW Es	+2.20 (n=11)	+8.40 (n=5)	+1.30	+0.80
HIGH Es (EEG)	+3.80 (n=5)	+7.50 (n=4)	-0.20	-3.00
LOW Es (EEG)	-5.70 (n=3)	+7.80 (n=4)	+4.30	+0.25

Table 7

Gorrelation Goefficients Among the Intuitive-Analytic (IN-AN) Questionnaire, Gognitive Style (S: Spatial; V: Verbal) Preference Test, Ego Strength (Es) Scale, Physiological Baseline Scores and Biofeedback Training Variables for Most Experimental Breakdowns of the Third Sample

PREDICTOR VARIABLE	CRITERION VARIABLE	EXPERIMENTAL GROUP	r	p
IN-AN	Es	SI (n=16)	-.42	.05
		SI-EMG (n=8)	-.83	.005
		VA-EMG (n=8)	-.73	.02
	IN-AN CHANCE	ALL SUBJEGTS (n=32)	-.57	.001
		VA (n=16)	-.50	.03
		EMC (n=16)	-.42	.05
		EEC (n=16)	-.73	.001
		SI-EEG (n=8)	-.74	.02
		RHSI (n=4)	-.94	.03
		RH (n=8)	-.73	.02
		LH (n=8)	-.82	.007
	IF BASELINE	EEG (n=16)	.43	.05
		LH (n=8)	.79	.01
	AI BASELINE	LH (n=8)	-.66	.04
	IF DIFFERENCE[a]	EEG (n=16)	.46	.04
		LHSI (n=4)	.97	.02
		LH (n=8)	.62	.05
	TRAINING[b]	VA-EMG (n=8)	-.86	.003
	MxD[c]	SI-EMG (n=8)	-.62	.05
		VA-EMC (n=8)	.69	.03
	SEX[d]	VA (n=16)	.50	.03
		LH (n=8)	.61	.05
Es	S	EMG (n=16)	.45	.04
	V	EMC (n=16)	-.42	.05
	Es CHANGE	ALL SUBJECTS (n=32)	-.47	.003
		SI (n=16)	-.81	.001
		SI-EMG (n=8)	-.72	.02
		EEG (n=16)	-.73	.001
		SI-EEG (n=8)	-.91	.001
		RHSI (n=4)	-.94	.03
		LHSI (n=4)	-.91	.04
		RH (n=8)	-.75	.02
		LH (n=8)	-.73	.02

Table 7

(Continued)

PREDICTOR VARIABLE	CRITERION VARIABLE	EXPERIMENTAL GROUP	r	p
Es	I_eA BASELINE	RHSI (n=4)	-.97	.02
	SEX	ALL SUBJECTS (n=32)	-.37	.02
		VA (n=16)	-.58	.009
		EMG (n=16)	-.48	.03
		VA-EEG (n=8)	-.73	.02
		LHVA (n=4)	-.98	.01
S	IN-AN CHANGE	ALL SUBJECTS (n=32)	-.38	.02
		EEG (n=16)	-.57	.01
		LH (n=8)	-.65	.04
	Es CHANGE	VA-EEG (n=8)	-.67	.04
		RHVA (n=4)	-.99	.005
	IF BASELINE	RHSI (n=4)	-.97	.01
		RHVA (n=4)	-.94	.03
		RH (n=8)	-.60	.05
		LH (n=8)	.61	.05
	AI BASELINE	LH (n=8)	-.60	.05
	IF DIFFERENCE	VA-EEG (n=8)	-.70	.03
		RHVA (n=4)	-.92	.04
	MxD	SI-EMG (n=8)	-.62	.05
V	IN-AN CHANGE	ALL SUBJECTS (n=32)	.37	.02
		EEG (n=16)	.52	.02
		LHVA (n=4)	.94	.03
		LH (n=8)	.63	.05
	Es CHANGE	VA-EMG (n=8)	-.65	.04
		VA-EEG (n=8)	.87	.003
		RHVA (n=4)	.95	.02
	IF BASELINE	RHSI (n=4)	.99	.003
	IF DIFFERENCE	VA-EEG (n=8)	.71	.02
		RHSI (n=4)	.89	.05
		RHVA (n=4)	.93	.04
	MxD	SI-EMG (n=8)	.63	.05
IN-AN CHANGE	Es CHANGE	ALL SUBJECTS (n=32)	-.42	.009
		VA (n=16)	-.49	.03
		EMG (n=16)	-.46	.04
	I_mA BASELINE	SI-EMG (n=8)	-.60	.05
	IF BASELINE	EEG (n=16)	-.51	.02
		LHSI (n=4)	-.91	.05
		LH (n=8)	-.93	.001

Table 7

(Continued)

PREDICTOR VARIABLE	CRITERION VARIABLE	EXPERIMENTAL GROUP	r	p
IN-AN CHANGE	AI BASELINE	EEG (n=16)	.55	.01
		SI-EEG (n=8)	.61	.05
		LHSI (n=4)	.96	.02
		RHVA (n=4)	.98	.008
		LH (n=8)	.81	.007
	IF DIFFERENCE	EEG (n=16)	-.60	.007
		SI-EEG (n=8)	-.66	.04
		LHSI (n=4)	-.96	.02
		LH (n=8)	-.91	.001
	TRAINING	EEG (n=16)	.42	.05
		SI-EMG (n=8)	-.60	.05
	SEX	LH (n=8)	-.66	.04
Es CHANGE	IF BASELINE	RHVA (n=4)	.89	.05
		RH (n=8)	.73	.02
	IF DIFFERENCE	EEG (n=16)	.44	.05
		VA-EEG (n=8)	.81	.007
		RHSI (n=4)	.94	.03
		RHVA (n=4)	.92	.04
		RH (n=8)	.90	.001
	TRAINING	EEG (n=16)	-.51	.02
I_mA BASELINE	I_mA DIFFERENCE[a]	EMG (n=16)	.85	.001
		SI-EMG (n=8)	.85	.004
		VA-EMG (n=8)	.92	.001
	TRAINING	SI-EMG (n=8)	.70	.03
	SEX	EMG (n=16)	.45	.04
I_mA DIFFERENCE	TRAINING	VA-EMG (n=8)	-.64	.05
IF BASELINE	AI BASELINE	EEG (n=16)	-.63	.004
		SI-EEG (n=8)	-.72	.02
		RHVA (n=4)	-.91	.05
		LHVA (n=4)	.95	.02
		RH (n=8)	-.71	.02
		LH (n=8)	-.61	.05
	IF DIFFERENCE	EEG (n=16)	.81	.001
		SI-EEG (n=8)	.87	.002
		LHSI (n=4)	.89	.05
		RH (n=8)	.76	.01
		LH (n=8)	.84	.004

Table 7

(Continued)

PREDICTOR VARIABLE	CRITERION VARIABLE	EXPERIMENTAL GROUP	r	p
IF BASELINE	HEMISPHERE[e]	VA-EEG (n=8)	.64	.04
	TRAINING	EEG (n=16)	-.49	.03
		SI-EEG (n=8)	-.70	.03
		RH (n=8)	-.61	.05
	SEX	EEG (n=16)	.41	.05
		LH (n=8)	.68	.03
I_eA BASELINE	AI BASELINE	EEG (n=16)	.56	.01
		VA-EEG (n=8)	.65	.04
		RH (n=8)	.60	.05
	SEX	RHVA (n=4)	.91	.05
AI BASELINE	IF DIFFERENCE	EEG (n=16)	-.64	.004
		SI-EEG (n=8)	-.69	.03
		VA-EEG (n=8)	-.61	.05
		LH (n=8)	-.79	.01
	HEMISPHERE	SI-EEG (n=8)	.77	.01
	TRAINING	SI-EEG (n=8)	.61	.05
		LHSI (n=4)	.97	.02
	SEX	SI-EEG (n=8)	-.80	.008
		LHSI (n=4)	-.97	.02
IF DIFFERENCE	TRAINING	EEG (n=16)	-.64	.004
		SI-EEG (n=8)	-.73	.02
		RH (n=8)	-.80	.009
		LH (n=8)	-.60	.05
TRAINING	SEX	LHSI (n=4)	-1.00	.001

[a] difference between physiological baseline score (e.g., "Session 0") and lowest of final four training session scores.

[b] dichotomous variable: Trained-Untrained

[c] "maximum drop" from baseline, i.e., per cent reduction of physiological activity from baseline relative to lowest daily average.

[d] dichotomous variable: Male-Female

[e] dichotomous variable: Left-Right

Table 8

Summary of Sex Differences

(1) Males displayed higher ego strength scores than females.

(2) Males displayed a greater post-training shift toward the intuitive mode than females.

(3) Untrained females displayed a greater post-training shift toward the intuitive mode than trained females.

(4) Males were associated with analytic scores and high ego strength, whereas females were associated with intuitive scores and low ego strength.

(5) Females displayed higher baseline EEG frequency, amplitude, and EMG amplitude than males.

(6) Males displayed more baseline EEG alpha than females.

FIGURE CAPTIONS

Figure 1. Simplified operational diagram of self-regulation of psychophysiological events and processes (Green & Green, 1975).

Figure 2. Mean per cent change from baseline ("Session 0") for spatial intuitive (SI; n=16) and verbal-analytic (VA; n=16) groups across sessions (disregarding feedback mode). Each score is the average per cent change for each feedback session relative to the average of three raw session scores (EEG- Hz; EMG- uV) obtained under no feedback conditions.

Figure 3. Mean per cent change from baseline ("Session 0") for EEG (n=16) and EMG (n=16) groups over sessions (disregarding cognitive style). Each score is the average per cent change for each feedback session relative to the average of three raw session scores (EEG- Hz; EMG- uV) obtained under no feedback conditions.

Figure 4. Mean integrated EMG amplitude (I_mA) for spatial-intuitive (SI; n=8) and verbal-analytic (VA; n=8) groups over sessions. Each score is the average of ten 2-minute epochs obtained during each 40-minute feedback session. "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

Figure 5. Mean integrated dominant EEG frequency (IF) for spatial-intuitive (SI; n=8) and verbal-analytic (VA; n=8) groups over sessions (disregarding hemisphere electrode placement). Each score is the average of ten 2-minute epochs obtained during each 40-minute feedback session. "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

Figure 6. Mean integrated dominant EEG frequency (IF) for left hemisphere spatial-intuitive (LHSI; n=4), right hemisphere spatial-intuitive (RHSI; n=4), left hemisphere verbal-analytic (LHVA; n=4), and right hemisphere verbal-analytic (RHVA; n=4) groups over sessions. Each score is the average of ten 2-minute epochs obtained during each 40-minute feedback session. "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

Figure 7. Mean integrated dominant EEG frequency (IF) for left hemisphere spatial-intuitive (LHSI; n=4), right hemisphere spatial-intuitive (RHSI: n=4), left hemisphere verbal-analytic (LHVA; n=4), and right hemisphere verbal-analytic (RHVA; n=4) groups over combined sessions (four sessions per week). Each score is the average of forty 2-minute epochs obtained during each week of training (ten epochs per day). "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

Figure 8. Mean integrated EEG amplitude (I_eA) for left hemisphere spatial-intuitive (LHSI; n=4), right hemisphere spatial-intuitive (RHSI; n=4), left hemisphere verbal-analytic (LHVA; n=4), and right hemisphere verbal-analytic (RHVA;n=4) groups over sessions. Each score is the average of ten 2-minute epochs obtained during each 40-minute feedback session. "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

Figure 9. Mean alpha index (AI) for left hemisphere spatial-intuitive (LHSI; n=4), right hemisphere spatial-intuitive (RHSI; n=4), left hemisphere verbal-analytic (LHVA; n=4), and right hemisphere verbal-analytic (RHVA; n=4) groups over sessions. Each score is the average of ten 2-minute epochs obtained during each 40-minute feedback session. "Session 0" is the average of three sessions without feedback and serves as the physiological baseline score.

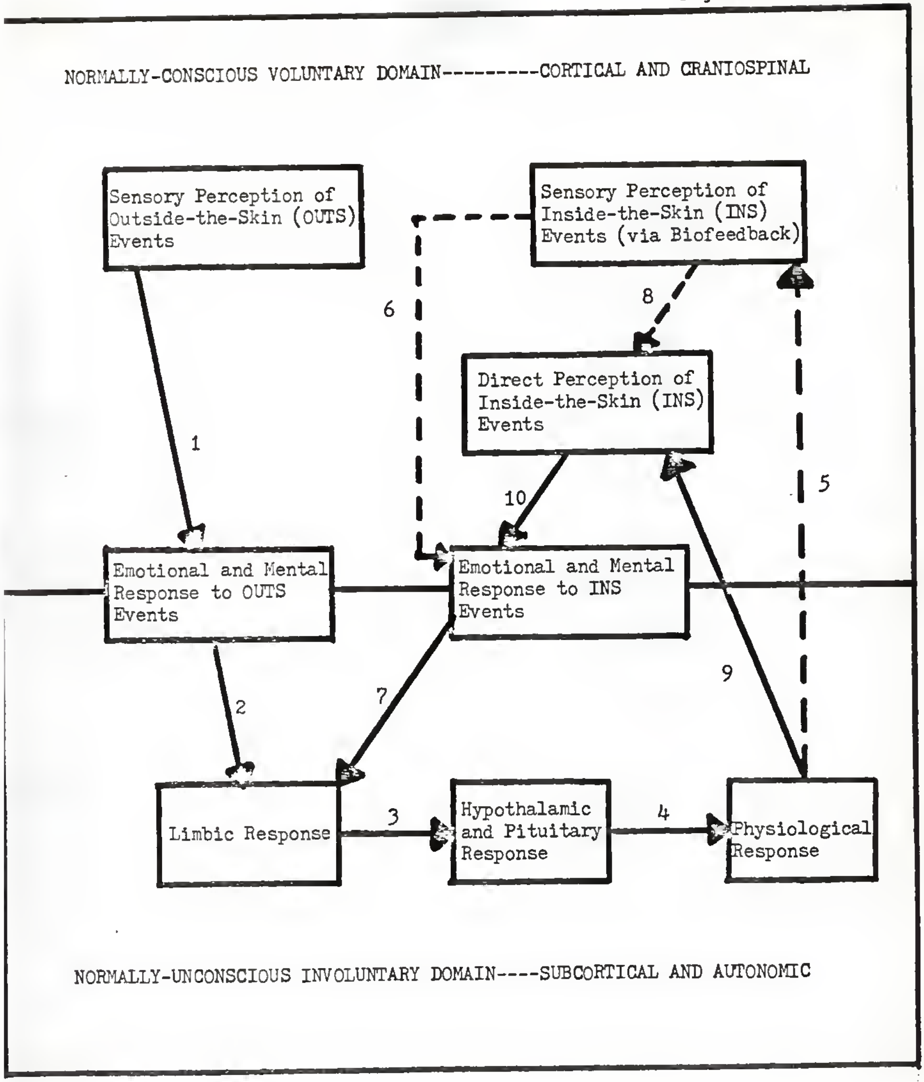

NORMALLY-CONSCIOUS VOLUNTARY DOMAIN---------CORTICAL AND CRANIOSPINAL
Sensory Perception of Outside-the-Skin (OUTS) Events
Sensory Perception of Inside-the-Skin (INS) Events (via Biofeedback)
Direct Perception of Inside-the-Skin (INS) Events
Emotional and Mental Response to OUTS Events
Emotional and Mental Response to INS Events
Limbic Response
Hypothalamic and Pituitary Response
Physiological Response
1
2
3
4
5
6
7
8
9
10
NORMALLY-UNCONSCIOUS INVOLUNTARY DOMAIN----SUBCORTICAL AND AUTONOMIC

Figure 2

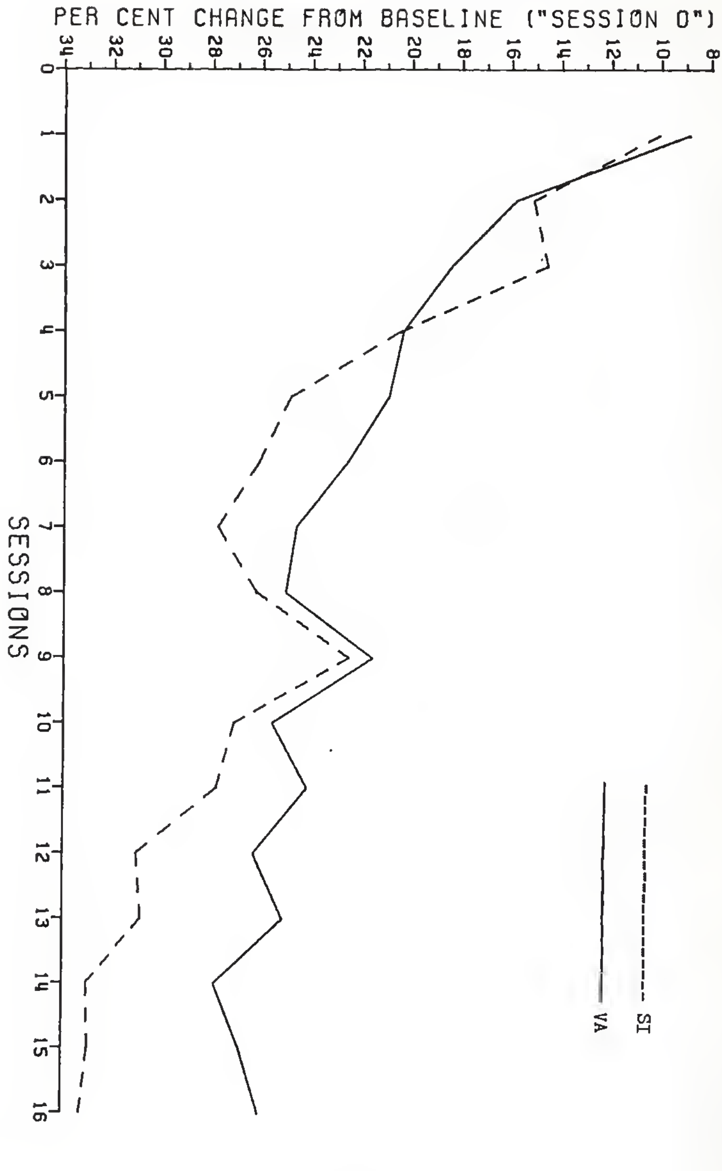

PER CENT CHANGE FROM BASELINE ("SESSION 0")
34
32
30
28
26
24
22
20
18
16
14
12
10
8
SESSIONS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SI
VA

Figure 3

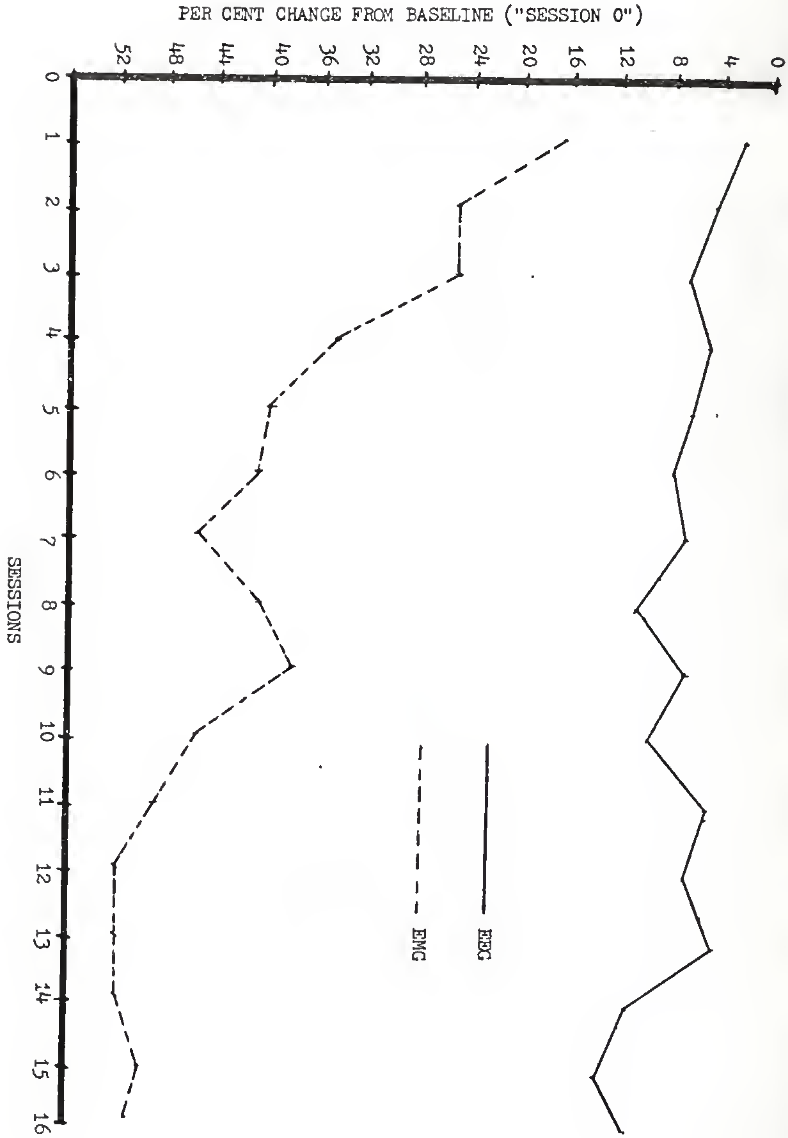
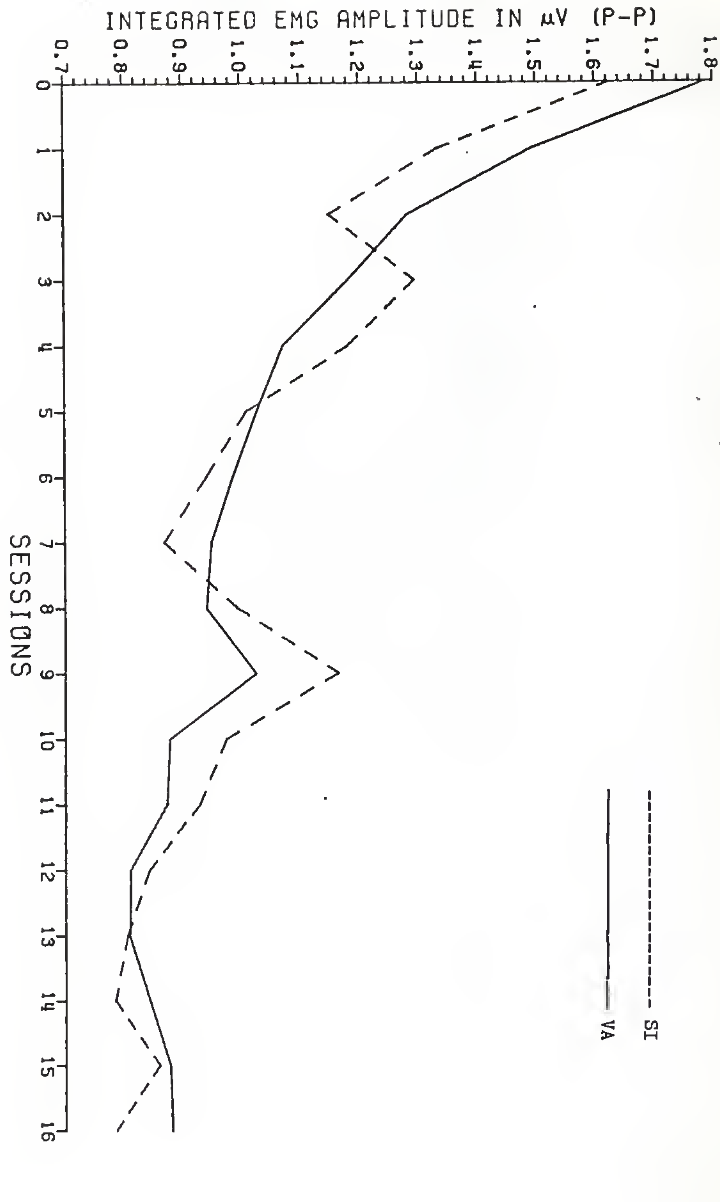

PER CENT CHANGE FROM BASELINE ("SESSION 0")
0
4
8
12
16
20
24
28
32
36
40
44
48
52
SESSIONS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
EEG
EMG

Figure 4



INTEGRATED EMG AMPLITUDE IN µV (P-P)
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
SESSIONS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SI
VA

Figure 5

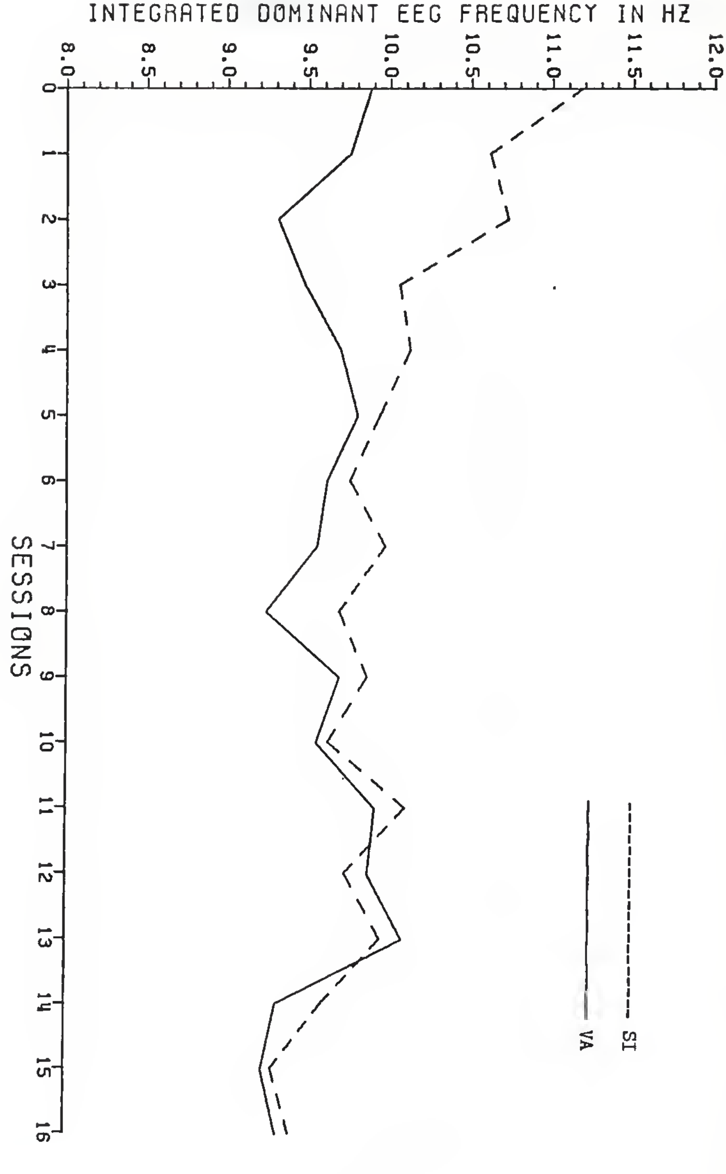
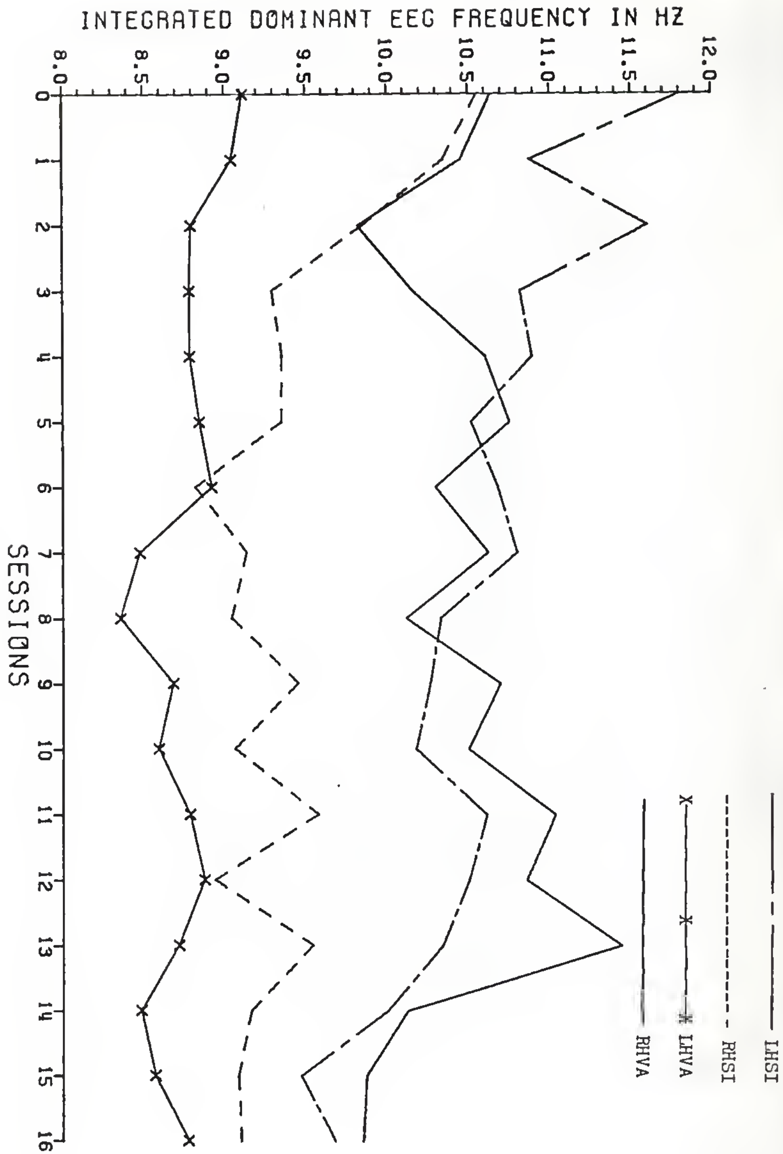
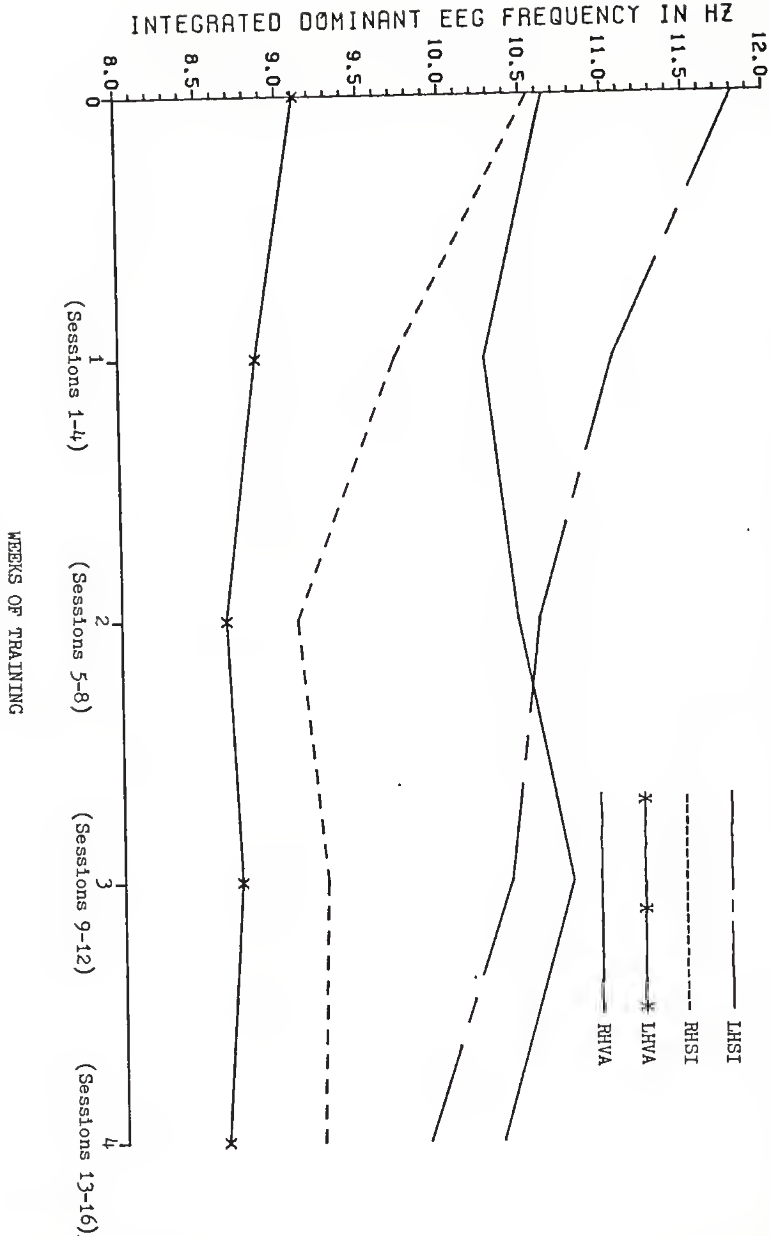

INTEGRATED DOMINANT EEG FREQUENCY IN HZ
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
SESSIONS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SI
VA

Figure 6



INTEGRATED DOMINANT EEG FREQUENCY IN HZ
SESSIONS
LHSI
RHSI
LHVA
RHVA

Figure 7



INTEGRATED DOMINANT EEG FREQUENCY IN HZ
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
0
1 (Sessions 1-4)
2 (Sessions 5-8)
3 (Sessions 9-12)
4 (Sessions 13-16)
WEEKS OF TRAINING
LHSI
RHSI
LHVA
RHVA

Figure 8

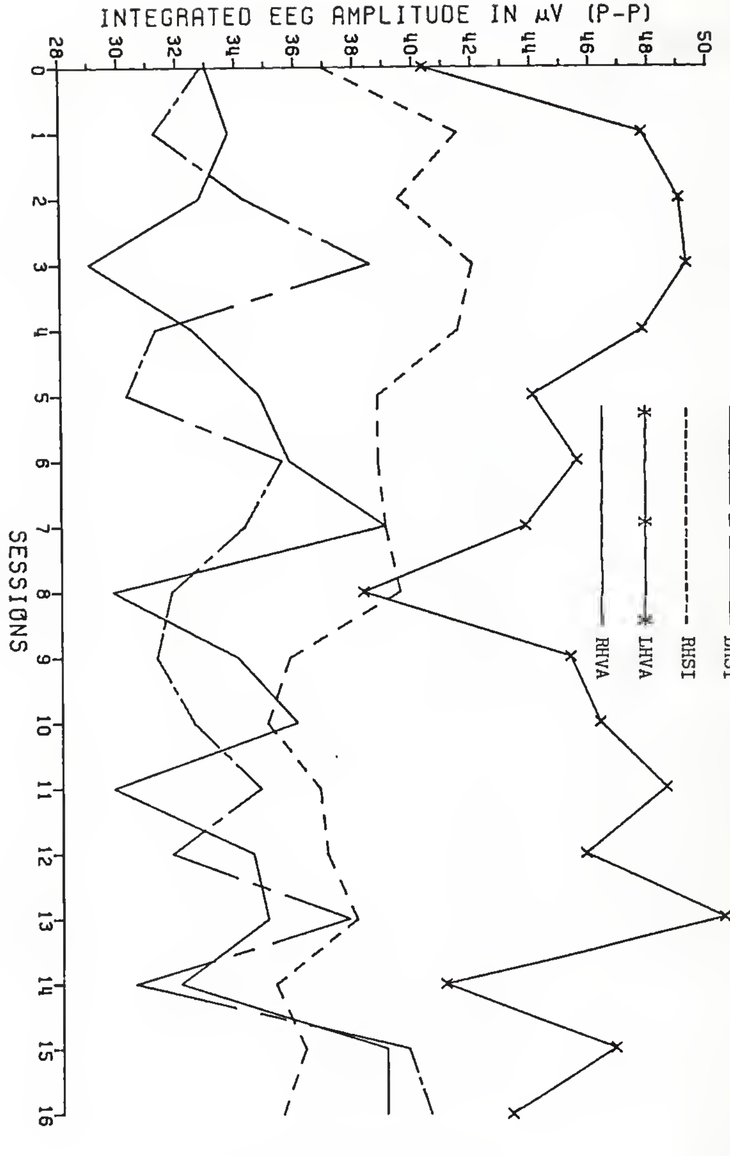
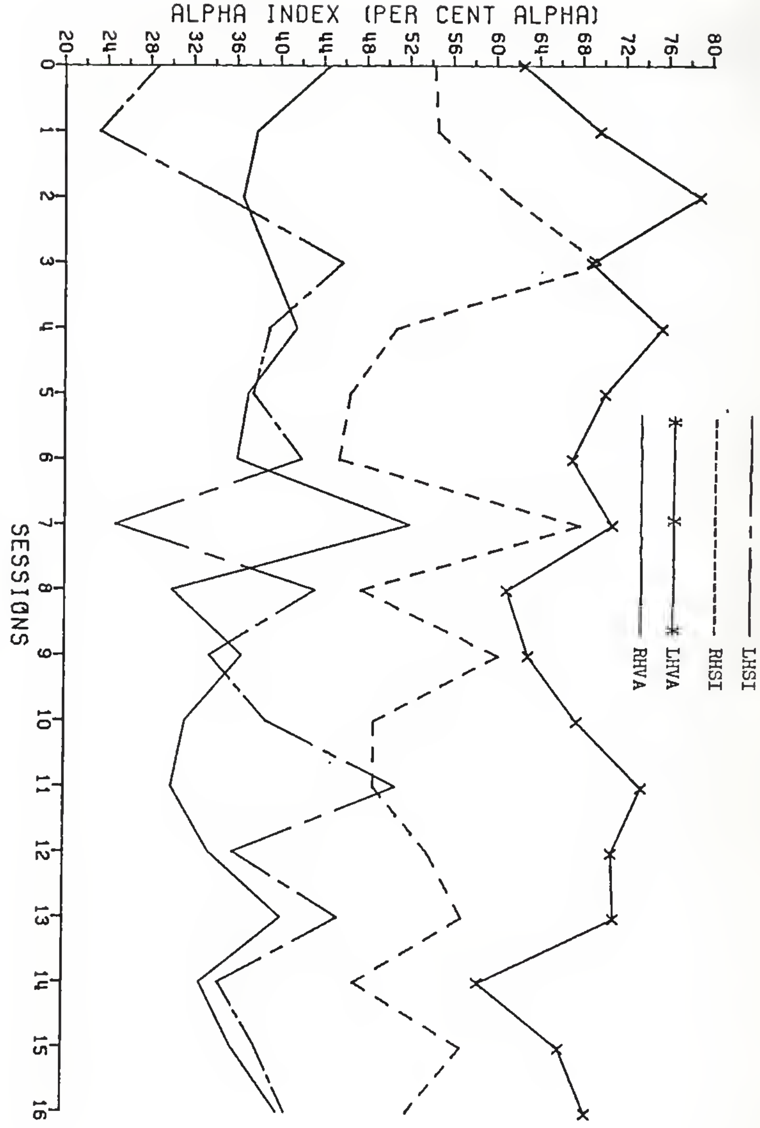

INTEGRATED EEG AMPLITUDE IN µV (P-P)
28
30
32
34
36
38
40
42
44
46
48
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SESSIONS
LHSI
RHSI
LHVA
RHVA

Figure 9


ALPHA INDEX (PER CENT ALPHA)
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SESSIONS
LHSI
RHSI
LHVA
RHVA

BIOFEEDBACK TRAINING AND COGNITIVE STYLE:
AN ELECTROPHYSIOLOGICAL LEARNING STUDY

by

DALE MARTIN PATTERSON

B. A., Western Washington University, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1978

Previous research has suggested that performance in biofeedback training is predictable from individual differences on personality scales and social psychological dimensions. Pre-post changes on these measures have also been reported and attributed to the training process. Combining a cognitive preference measuring instrument with a perceptual response measure, the present study further investigated the relationship between "cognitive style" and the efficiency of the learning process within low arousal biofeedback training. In addition, recent work evidencing differential task laterality by cognitive style suggests that relative superiority in EEG feedback training will be displayed by individuals whose cognitive preferences match their trained hemisphere's lateralized function (i.e., training of "preferred" hemisphere). This hypothesis, as well as the hypothesis that pre-post cognitive style/personality changes are attributable to the training process, was also tested.

Extreme scores on Baumgardner's Intuitive-Analytic Questionnaire and Galin and Ornstein's Word Shape (Spatial-Verbal) Preference Test were used to obtain spatial-intuitive and verbal-analytic groups (8 males, 8 females each) from 693 subjects (aged 18-56, controlled for lefthandedness and lefthandedness background for 3 days (120 min.) of baseline recording and 16 days (640 min.) of biofeedback training (dominant EEG frequency or frontalis EMG amplitude lowering). Spatial-intuitive subjects preferred a generalized cognitive strategy based on implicit, emotional, or "gut feeling" cues and displayed relatively more spatial than verbal responses in a timed, free-choice situation. Verbal-analytic subjects preferred a

strategy based on explicit, logico-rational, or "rule following" cues and displayed more verbal than spatial responses. Subjects were randomly assigned to left hemisphere EEG (O_7-T_3, n = 4), right hemisphere EEG (O_8-T_4, n = 4), or frontalis EMG (n = 8) training. Following baseline recording, subjects were given continuous-analogue, auditory feedback proportional to electrophysiological activity, verbal feedback (every 4 min.) of 2 min. integrated activity, and written feedback (weekly) of per cent changes in activity from baseline and from the preceding week. Finally, Barron's Ego Strength Scale was administered (pre-post).

Although no resting EMG differences were found, spatial-intuitive subjects displayed significantly higher resting EEG frequency, significantly lower amplitude, and significantly less alpha than verbal-analytic subjects, but only within the left hemisphere. Disregarding cognitive style, the EMG group (n = 16) displayed significantly greater and more rapid reductions in electrophysiological activity (from baseline) than the EEG group (n = 16), indicating that task difficulty was a salient variable during training. Regardless of hemisphere electrode placement, spatial-intuitive EEG groups effected significant reductions in electrophysiological activity, whereas verbal-analytic EEG groups did not. However, the left hemisphere-trained spatial-intuitive group showed significantly greater (but less rapid) reductions in activity than the right hemisphere-trained spatial-intuitive group. Although both EMG groups displayed significant reductions in electrophysiological activity, no differences between spatial-intuitive and verbal-analytic subjects were found. Significant pre-post changes on Baumgardner's questionnaire displayed by verbal-analytic subjects in the intuitive direction were negatively related to success in training. Pre-post ego strength increases were less consistently reliable, but were positively related to success in training.

Results suggest that (1) cognitive style (as here defined) predicts performance in low arousal biofeedback training as a function of task difficulty, (2) left hemisphere EEG activity predicts both cognitive style and performance in EEG feedback training better than activity of either the "preferred" or "nonpreferred" hemisphere, (3) somato-cognitive movement toward low arousal requires the coordinated activity of both cerebral hemipsheres and may facilitate the acquisition of a passive set resembling the spatial-intuitive cognitive mode, and (4) pre-post changes in cognitive style cannot be unequivocally attributed to the biofeedback training process.